

# MIT ENERGY INITIATIVE External Advisory Board Briefing Book

October 2018



**MIT***ei*  
MIT Energy Initiative

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To access the links in this document and an appendix of articles featuring MITEI research and activities from MIT News and external media sources, visit the online External Advisory Board Briefing Book at: [energy.mit.edu/eab2018](http://energy.mit.edu/eab2018)

# Letter from the Director

Dear External Advisory Board members,

This past year has brought some exciting developments for MITEI as we continue to advance new energy research; connect industry, government, and academia; and educate bright, talented students to address the world's energy challenges.

One particularly noteworthy development is a first-of-its-kind collaboration to advance fusion research. Founding member Eni has made two major investments to fund fusion research projects: a \$50 million investment in a new private company with MIT roots, Commonwealth Fusion Systems (CFS)—much of which will support research at the Institute—and a commitment of approximately \$2 million for projects within the MIT Plasma Science and Fusion Center's newly created Laboratory for Innovation in Fusion Technologies. The goal of this collaboration is to develop a working pilot fusion plant and reach commercialization of fusion energy within 15 years. It's an exciting new chapter for a potentially inexhaustible source of energy, one that could significantly advance the transition toward a low-carbon energy future and help create a better world.

CFS has joined MITEI as a new class of member that is geared specifically toward energy startups. This new membership class will enable these entrepreneurial companies and larger, more established energy companies to learn from each other—sharing knowledge of the energy sector and accelerating commercialization of new technologies to improve our global energy systems. We have also added many new members for our Low-Carbon Energy Centers, bringing the total number of members to 19 at the end of FY2018.

Other highlights from the past year include our 2017 Annual Research Conference, which brought a diverse array of speakers to discuss decarbonization, digitization, and decentralization of the energy sector, and was well received by our members and other invited guests. The latest in our “Future of” report series, *The Future of Nuclear Energy in a Carbon-Constrained World*, was released in September with events in Europe, Asia, and the U.S., and gathered a wide audience of policymakers, regulators, and academics to discuss the opportunities and challenges affecting the ability of nuclear energy technologies to meet U.S. and global energy needs and play a vital role in climate solutions.

Our education department also continues to grow with new courses, programming, and educational opportunities, such as the summer career skills workshop offered to undergraduate student researchers. Professors Robert Jaffe and Washington Taylor, both of physics, have released their new textbook, *The Physics of Energy*, a definitive resource for anyone from students, scientists, and engineers to energy industry professionals and interested citizens.

Thank you for all that you do to support MITEI and our mission to realize a low-carbon energy future. As always, please feel free to reach out at any time with your thoughts, questions, or ideas about our work.

Best,



Robert C. Armstrong  
Director, MIT Energy Initiative

# Overview and Mission

The MIT Energy Initiative (MITEI) is MIT’s hub for energy research, education, and outreach. Through these three pillars, MITEI plays an important catalytic role in accelerating responses to the many challenges facing our global energy system—developing technologies and solutions to deliver clean, affordable, and plentiful sources of energy. The Initiative’s mission is to create low- and no-carbon solutions that will efficiently and sustainably meet global energy needs while minimizing environmental impacts, dramatically reducing greenhouse gas emissions, and mitigating climate change.

To advance this mission, MITEI brings together researchers from across the Institute and facilitates collaborations with industry and government. MITEI and its member companies and organizations support hundreds of research projects across the Institute, including those awarded through the MITEI Seed Fund Program for innovative early-stage energy research projects.

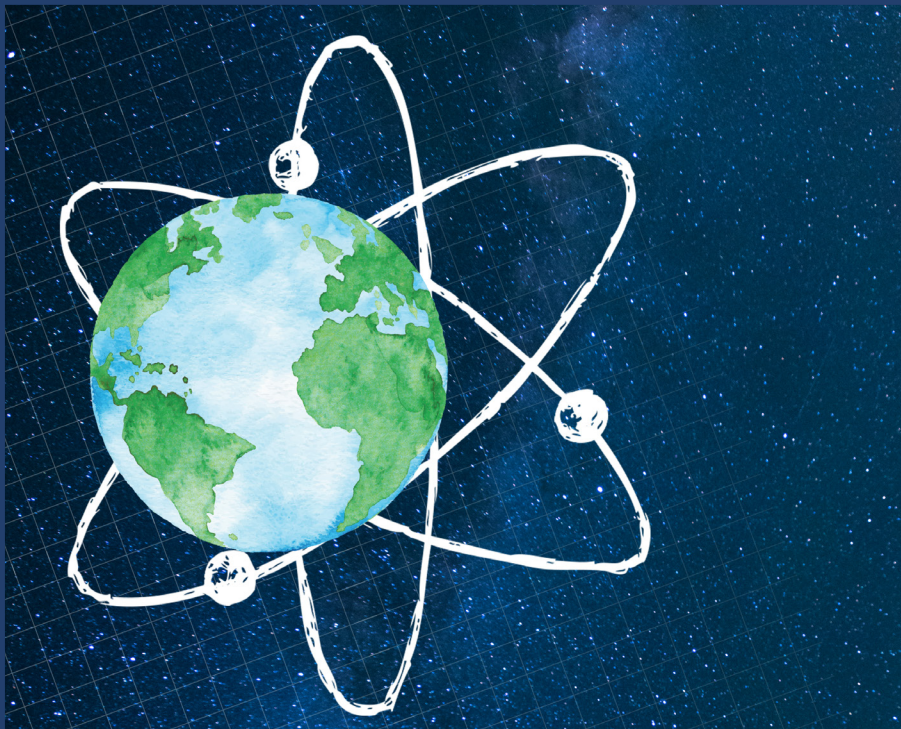
The Initiative also delivers comprehensive analyses for policy makers and regulators, such as the “Future of” study series, the latest of which includes [The Future of Nuclear Energy in a Carbon-Constrained World](#), published in September 2018 with the Nuclear Science and Engineering Department, and [The Future of Solar Energy](#) (2015). A new series of studies by MITEI examine rapidly changing segments of the energy sector. The first in this series was the 2016 [Utility of the Future](#) study and report examining the electricity services sector; a study currently underway, [Mobility of the Future](#), examines the light mobility segment of the transportation sector.

As a vital component of MIT’s Plan for Action on Climate Change and MITEI’s research program, the [Low-Carbon Energy Centers](#) present opportunities for faculty, students, industry, and government to advance research and development in key technology areas for addressing climate change, from solar energy to electric power systems, nuclear energy, and other areas.

MITEI leads Institute [energy education](#) efforts and has engaged thousands of undergraduate, graduate, and postdoctoral students through sponsored research opportunities and other programs—preparing the next generation of innovators, entrepreneurs, and policymakers to collaborate on solutions to global energy challenges. Energy education programs include the Energy Studies Minor, Undergraduate Research Opportunities Program in energy, short modules during the Independent Activities Period, an energy-focused freshman pre-orientation program, the graduate Society of Energy Fellows, and other initiatives. Faculty associated with MITEI help shape energy education at both the undergraduate and graduate levels by teaching, advising, and developing new curricula.

MITEI’s comprehensive [outreach efforts](#) foster dialogue within the academic research community and provide the public with context on current energy issues. In addition to informing public policy through research reports, MITEI facilitates this exchange of information by hosting and sponsoring events on campus and by supporting faculty and staff participation in external events. The MITEI communications team also develops content to highlight MIT energy researchers, students, and their work across print and digital platforms, such as [Energy Futures](#) magazine, MITEI’s website, and social media, as well as through media outreach.

# FY2018 Highlights



In September 2018, MITEI released *The Future of Nuclear Energy in a Carbon-Constrained World*, with events in the U.S., Europe, and Asia. The latest in MITEI's "Future of" series, this comprehensive report discusses the opportunities and challenges affecting the ability of nuclear energy technologies to meet U.S. and global energy needs and play a vital role in climate solutions.

*Graphic: Christine Daniloff*



Kouichi Murakami (left), general manager of corporate research and development at IHI Corporation, and MITEI Director Robert C. Armstrong sign the agreement for IHI's membership in MITEI's Center for Carbon Capture, Utilization, and Storage. *Photo: Kelley Travers*



Francis O'Sullivan (left), MITEI's director of research, talks with Christopher Knittel, the George P. Shultz Professor of Applied Economics, during a Low-Carbon Energy Center for Electric Power Systems workshop after the Annual Research Conference in 2017. *Photo: Bryce Vickmark*

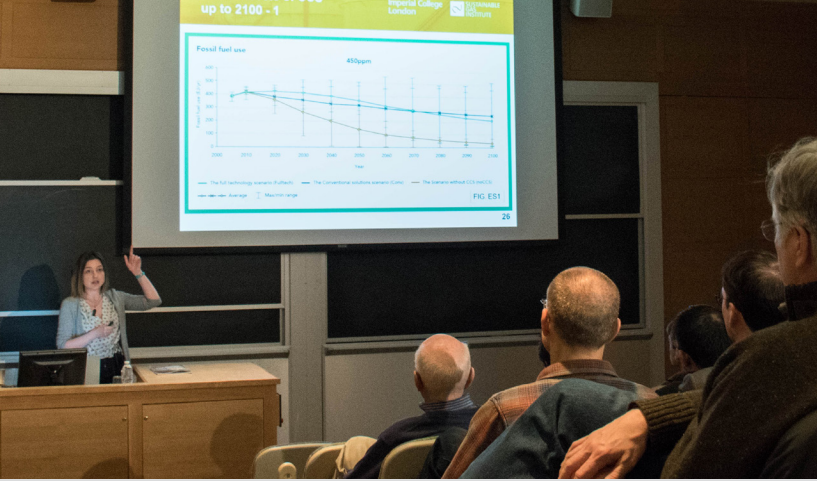
## Low-Carbon Energy Centers

MITEI continues to develop the Low-Carbon Energy Centers launched in the fall of 2015 as part of MIT's [Plan for Action on Climate Change](#). These research centers are dedicated to tackling the most pressing energy challenges related to climate change from key technological and economic perspectives. Each of the seven centers has a distinct focus: carbon capture, utilization, and storage; electric power systems; energy bioscience; energy storage; materials for energy and extreme environments; advanced nuclear energy systems; and solar energy. Fusion, one of the original eight focal areas, will now be supported through the MIT Plasma Science and Fusion Center's newly created Laboratory for Innovation in Fusion Technologies.

To solve the pressing challenges of decarbonizing the energy sector with advanced technologies, it is vital that experts across all disciplines and sectors are engaged. Through the Low-Carbon Energy Centers, MITEI facilitates this important collaboration: enabling faculty members from across MIT to converge around specific technology research areas and work with industry and government members to advance and expand the portfolio of existing MITEI-facilitated research in these areas. Together, MIT researchers and center members are working to develop and scale the technologies that will move us toward a low-carbon energy future.

As of the end of FY2018, MITEI has generated \$85+ million in sponsored research activity related to the Low-Carbon Energy Centers. Nineteen new and current MITEI members have committed support for the centers—with some members supporting multiple centers—and interest continues to grow.

Read more about new center members in the **Members** section.

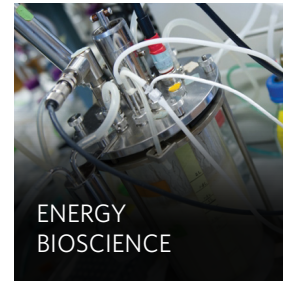
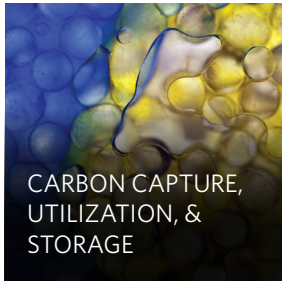


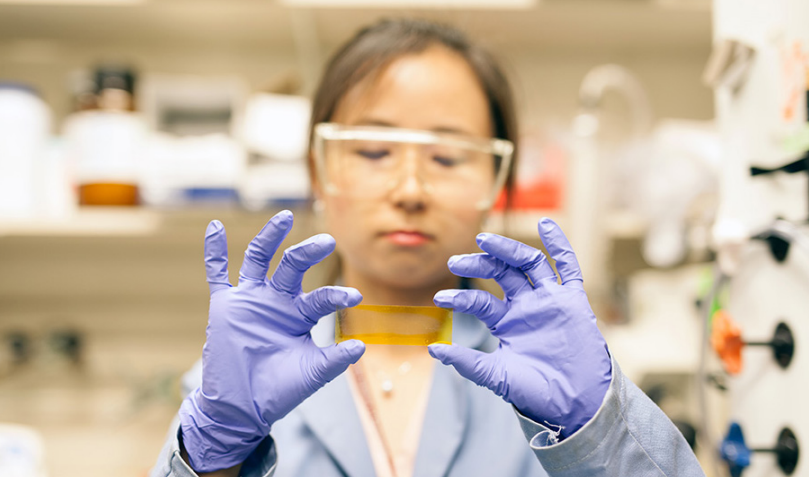
Sara Budinis, a research associate at the Sustainable Gas Institute, discusses the current state of knowledge regarding “unburnable carbon”—the fossil fuel reserves that cannot be combusted if we are to meet our carbon budget—at a seminar sponsored by the Low-Carbon Energy Center for Carbon Capture, Utilization, and Storage. *Photo: CeCe Vander Laan*



Lihong (Wendy) Duan (left), manager of the Asia Pacific Energy Partnership Program at MITEI, and Singh Intrachotoo, chief advisor of MQDC’s Research & Innovation for Sustainability Center, shake hands during a signing ceremony to launch MQDC’s membership in MITEI’s Center for Electric Power Systems Research. *Photo: courtesy of MQDC*

## MITEI’s Low-Carbon Energy Centers





MIT postdoc Grace Han handles a new chemical composite that could provide an alternative to fuel by functioning as a kind of thermal battery.

*Photo: Melanie Gonick*



In spring 2018, MITEI awarded nine grants totaling \$1,350,000 through its Seed Fund Program. Pictured above are Seed fund awardees (from left) Ahmed Ghoniem, Betar Gallant, Karthish Manthiram, and Bilge Yildiz. *Photo: Kelley Travers*

## Research & Analysis

MITEI's research portfolio reflects the Initiative's goal of advancing low-carbon energy via diverse channels, from renewable energy and energy efficiency to carbon management technologies. Solar energy technology and policy is the largest single area of funded research. The portfolio also includes projects geared toward meeting contemporary energy needs through the efficient use of conventional energy sources.

MITEI members have sponsored approximately 900 projects to date, many involving collaboration between MIT researchers and member researchers. Approximately 30 percent of MIT faculty has engaged with MITEI's programs.

### MITEI Research Program Highlights

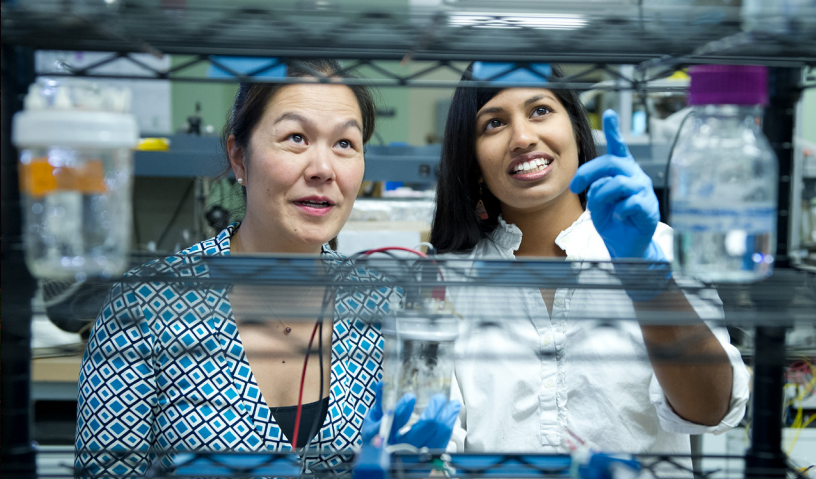
- **Funding for early-stage research:** Supporting promising energy research across a wide range of disciplines is one of MITEI's core tenets. This spring, MITEI awarded nine early-stage MIT energy research projects \$150,000 each, for a total of \$1.35 million. Including the 2018 grants, MITEI has supported 170 energy-focused projects with grants totaling \$22.75 million. These projects have covered the full spectrum of energy research areas, from fundamental physics and chemistry to policy and economics, and have drawn from all five MIT schools and 28 departments, labs, and centers.
- **Studies and reports:** This year, a team of researchers led by MIT Department of Nuclear Science and Engineering TEPCO Professor Jacopo Buongiorno have finalized the multidisciplinary study *The Future of Nuclear Energy in a Carbon-Constrained World*, the eighth in MITEI's "Future of" report series. The study was released in Europe on September 3, 2018, with subsequent events in





Plant nanobionics, a new research area pioneered by Carbon P. Dubbs Professor of Chemical Engineering Michael Strano's lab, aims to give plants novel features by embedding them with different types of nanoparticles. The group's goal is to engineer plants to take over many of the functions now performed by electrical devices.

*Photo: Seon-Yeong Kwak*



Professor Evelyn Wang (left) and Heena Mutha PhD '17 have developed a nondestructive method of quantifying the detailed characteristics of carbon nanotube samples—a valuable tool for optimizing these materials for use as electrodes in a variety of practical devices.

*Photo: Stuart Darsch*

the U.S. and Asia. The [Mobility of the Future](#) study is steadily progressing as well. This study is exploring how consumers and markets will respond to potentially disruptive technologies, business models, and government policies in the transportation sector. See more details on each of these studies in the **MITEI Studies** section.

- **Working papers:** The Institute also released working papers written by MITEI staff, faculty affiliates, and graduate students on subjects ranging from energy storage to the changing structure of the electricity grid.
- **Low-Carbon Energy Center meetings:** The Centers for Carbon Capture, Utilization, and Storage; Energy Storage; and Electric Power Systems each held several workshops and meetings to discuss with their members the latest research results and new directions of technology development.

## Faculty Research Highlights

### MATERIALS SCIENCE

- [Understanding drop coalescence](#)  
A new MITEI-funded study by researchers in the departments of mechanical engineering and mathematics offers a detailed, mathematical understanding of drop coalescence, which may help researchers understand how biological or chemical substances are spread by rain or other sprays in nature. They could also serve as a guide for droplet-based designs, such as microfluidic chips.
- [Fabrication of new materials](#)  
MIT researchers Stefanie Jegelka and Elsa Olivetti have demonstrated a novel system using artificial intelligence techniques to help identify methods of fabricating materials, especially those that look promising in computer simulations.

## ENERGY STORAGE

- [\*\*New approaches to thermal storage\*\*](#)  
A chemical composite developed by MIT postdocs Grace Han and Huashan Li and Professor Jeffrey Grossman could be used to store heat and release it on demand.
- [\*\*Optimizing carbon nanotube electrodes\*\*](#)  
Professor Evelyn Wang and Heena Mutha PhD '17 have developed a nondestructive method of quantifying the detailed characteristics of carbon nanotube samples—a valuable tool for optimizing these materials for use as electrodes in a variety of practical devices.

## NUCLEAR ENERGY

- [\*\*A new era in fusion research at MIT\*\*](#)  
With the goal of developing a working fusion power plant within the next 15 years, Italian energy company and MITEI founding member [Eni S.p.A.](#) has reached an agreement with MIT to fund fusion research projects run out of the [MIT Plasma Science and Fusion Center](#)'s newly created Laboratory for Innovation in Fusion Technologies. Eni also announced a commitment to a \$50 million investment in a new private company with roots at MIT, [Commonwealth Fusion Systems](#).
- [\*\*From coolants to a carbon-constrained world\*\*](#)  
Undergraduate Ka-Yen Yau is helping to improve computational modeling that could significantly speed up the licensing of new types of nuclear reactors.

## SOLAR ENERGY

- [\*\*Technique allows rapid screening for new types of solar cells\*\*](#)  
An approach developed by Associate Professor Tonio Buonassisi could bypass the time-consuming steps currently needed to test new photovoltaic materials.
- [\*\*Optimizing nanostructures for energy devices\*\*](#)  
MIT researcher William Tisdale and colleagues have created quantum dot films that provide unprecedented high performance in solar cells, LEDs, and thermoelectric systems.

## ELECTRIC POWER SYSTEMS

- [\*\*How flexible nuclear operation can help add more wind and solar to the grid\*\*](#)  
An optimization model developed by researchers at MITEI and Argonne National Laboratory shows operating nuclear plants flexibly can reduce electricity costs, increase revenue for nuclear plants, and cut CO<sub>2</sub> emissions in electric power systems.

## TRANSPORTATION

- [\*\*Getting the world off dirty diesels\*\*](#)  
Using computer simulation analysis, MIT researchers Daniel Cohn and Leslie Bromberg have developed a conceptual design for a half-sized gasoline engine that would be as efficient and powerful as the full-sized diesel engines now used in heavy-duty trucks—without their high emissions of air pollutants and greenhouse gases.

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## ENERGY AND CLIMATE ECONOMICS AND POLICY

- [\*\*Natural resource negotiations for mutual gains\*\*](#)  
Bruno Verdini, MIT researcher and professor of urban planning and negotiation, has produced step-by-step guidelines for performing high-stakes natural resources negotiations that succeed—even after decades of mistrust, confrontation, and deadlock.
- [\*\*Charting gas and oil's future in a decarbonizing world\*\*](#)  
A new analytical method from the MIT Joint Program on the Science and Policy of Global Change addresses the dynamic nature of the petroleum industry, enabling more accurate predictions for changes in oil production costs.
- [\*\*Study: Health benefits will offset cost of China's climate policy\*\*](#)  
A study led by professors Noelle Eckley Selin and Valerie Karplus projects that a four percent reduction per year in China's carbon dioxide emissions should net \$339 billion in health savings by 2030.
- [\*\*Carbon taxes could make significant dent in climate change\*\*](#)  
An analysis by researchers including former MIT postdoc Justin Caron, MIT Joint Program on the Science and Policy of Global Change Co-Director John Reilly, and National Renewable Energy Laboratory researchers compared carbon-pricing approaches to determine which could be most effective in helping reduce emissions, and which would be most equitable and have bipartisan appeal.

## ADDITIONAL LOW-CARBON ENERGY RESEARCH

- [\*\*Cooling buildings worldwide\*\*](#)  
A fundamental analysis by MIT researchers Tianyi Chen, Omar Labban, Leslie Norford, and John Lienhard confirms that proposed new approaches to air conditioning could significantly reduce the energy required to cool and dehumidify indoor spaces—an escalating need as populations grow and the climate warms.
- [\*\*Projecting the impacts of climate change\*\*](#)  
Researchers at the MIT Joint Program on the Science and Policy of Global Change propose a self-consistent modeling framework to assess climate impacts across multiple regions and sectors.

## ENERGY IN THE DEVELOPING WORLD

- [\*\*Making appliances and energy grids more efficient\*\*](#)  
The Tata Center for Technology and Design is building a high-efficiency, affordable electric motor that could have a huge impact in India, which is home to as many as half a billion ceiling fans.
- [\*\*Tata Center adds eight new projects to its 2018-2019 portfolio\*\*](#)  
Tata Center principal investigators receive funding and support for projects seeking an impact in the developing world.

## MITEI Studies

### MOBILITY OF THE FUTURE STUDY

The multidisciplinary Mobility of the Future study, currently in progress, is exploring how consumers and markets will respond to potentially disruptive technologies, business models, and government policies. The research group, which has been meeting since August 2016, defines the scope of the study as ground transportation with an emphasis on the movement of people. The study is part of MIT's Plan for Action on Climate Change.

The study is led by faculty chair William H. Green, a professor of chemical engineering, and executive director Randall Field of MITEI. It is supported by energy, automotive, and infrastructure companies whose representatives are providing industry perspectives on mobility problems that require solutions. Sponsors include Alfa, BP, Chevron, ExxonMobil, Ferrovial, General Motors, Saudi Aramco, Shell, Equinor, and Toyota Mobility Foundation.

The study has undertaken analyses in many important areas of mobility including projection of the future cost of battery packs for electric vehicles, assessment of fuel consumption and fleet composition under various climate policy scenarios, and impact of various mobility services on mode choice for various types of cities. The study team—which includes faculty, researchers, graduate students, and postdocs—is in the process of completing, compiling, and analyzing the work of all eight workstreams to develop a final report on the findings in late 2019.

### THE FUTURE OF NUCLEAR ENERGY IN A CARBON-CONSTRAINED WORLD

A team of researchers led by MIT Department of Nuclear Science and Engineering professor Jacopo Buongiorno, who leads the Low-Carbon Energy Center for Advanced Nuclear Energy Systems (CANES), have released the multidisciplinary study *The Future of Nuclear Energy in a Carbon-Constrained World*, the eighth in MITEI's "Future of" report series. The team consists of seven MIT faculty members from across the Institute, as well as two Harvard University faculty members and four external consultants. The study, released in September 2018 with events in the U.S., Europe, and Asia, provides an objective assessment of the opportunities and challenges affecting the ability of nuclear energy technologies to meet U.S. and global energy needs in the context of the imperative to dramatically reduce carbon emissions and address climate change.

### THE FUTURE OF ENERGY STORAGE

A team of researchers began meeting in FY2018 to prepare for developing a comprehensive, multidisciplinary *Future of Storage* study. The study will consider key storage technologies that could support future electricity systems heavily reliant on variable renewable energy (VRE) resources such as wind and solar photovoltaic generation. The study will focus on practical system transformation pathways and the role of government in market design and regulation, research, and deployment support to advance storage technologies over the next two decades. It will also consider how storage interacts with other strategies, such as increased load flexibility and expanded transmission networks that might be part of a cost-effective approach to accommodate a VRE-rich generation mix.

## Reports and Studies

A selection of MITEI-supported reports and studies published in FY2018.

**Justin G. Chen et al. *A symmetry measure for detecting changes in mode shapes*. November 2017.**

<http://bit.ly/symmetry-measure>

Creates a new model for damage detection in infrastructure systems based on the inherent geometric symmetry of most real life infrastructure systems. Funded by Shell through MITEI.

**David M. Hart et al. *Energy storage for the grid: Policy options for sustaining innovation*. April 2018.**

<http://bit.ly/grid-policy>

Investigates policy options for transitioning the grid to a low-carbon energy future by examining pathways to bring electric power sector emissions to zero with the help of grid-scale energy storage.

**Howard Herzog et al. *Developing a consistent database for regional geologic CO<sub>2</sub> storage capacity worldwide*. July 2017.** <http://bit.ly/regional-carbon-storage>

Assesses the geologic storage capacity to determine worldwide potential for carbon dioxide capture and storage. Develops a method to generate first-order estimates of storage capacity requiring minimal data to characterize a geologic formation. Funded by ExxonMobil through MITEI.

**Jesse Jenkins et al. *Enhanced Decision Support for a Changing Electricity Landscape: The GenX Configurable Electricity Resource Capacity Expansion*. November 2017.** <http://bit.ly/GenX-model>

Describes the formulation of “GenX,” a highly-configurable electricity resource capacity expansion model that incorporates several state-of-the-art improvements in electricity system modeling to offer improved decision support for a changing electricity landscape.

**Heather Kulik et al. *Accelerating chemical discovery with machine learning: Simulated evolution of spin crossover complexes with an artificial neural network*. February 2018.** <http://bit.ly/simulated-evolution>

Uses machine learning to accelerate the discovery of new inorganic materials. Funded through a MITEI seed grant.

**John Lienhard et al. *Sodium hydroxide production from seawater desalination brine: Process design and energy efficiency*. April 2018.** <http://bit.ly/sodium-hydroxide>

Develops and models a process for sodium hydroxide production from seawater desalination brine using membrane chlor-alkali electrolysis. Includes reduced environmental impact and increase in overall water recovery. Funded through a Cadagua/Ferrovia industry collaboration.

**John Lienhard et al. *Utilization of desalination brine for sodium hydroxide production: Technologies, engineering principles, recovery limits, and future directions*. November 2017.**

<http://bit.ly/desalination-brine>

Investigates methods for producing sodium hydroxide from seawater reverse osmosis brine for internal reuse, and concludes that bipolar membrane electro dialysis appears to have the best potential to meet the techno-economic requirements of small-scale production. Funded through a Cadagua/Ferrovia industry collaboration.

**Justin Montgomery et al. *Spatial variability of tight oil well productivity and the impact of technology.* June 2017. <http://bit.ly/tight-oil-wells>**

Examines production and engineering data from thousands of tight oil wells to demonstrate that the role of technological learning has been overestimated in tight oil wells by current, less accurate methods, which fail to account for shifts of drilling activity toward best acreage. Funded through an MIT Energy Fellowship.

**Aurelien Mordret et al. *Continuous monitoring of high-rise buildings using seismic interferometry.* November 2017. <http://bit.ly/high-rise-buildings>**

Using data from the MIT Green Building, this paper examines a new seismic deconvolution interferometry-based approach to continuous monitoring of infrastructure systems to demonstrate the efficacy of the proposed approach. Funded by Shell through MITEI.

**Elsa Olivetti et al. *A set of papers on information extraction using natural language processing and machine learning.* September-December 2017. <http://bit.ly/info-extraction>**

Develops pipeline for extracting information from peer-reviewed academic literature across a range of inorganic solid-state materials synthesis approaches. Demonstrates the viability of a natural language processing approach. Funded through a MITEI seed grant.

**Roland Pellenq et al. *Impact of nanoporosity on hydrocarbon transport in shales' organic matter.* January 2018. <http://bit.ly/hydrocarbon-transport>**

Investigates hydrocarbon transport using statistical physics and molecular dynamics, creating realistic molecular models of kerogen phases. The research is related to the growing attention toward shale gas. Funded by the Shell/Schlumberger Xshale program and the MIT-CNRS lab, enabled through MITEI.

**Roland Pellenq et al. *Role of city texture in urban heat islands at nighttime.* March 2018. <http://bit.ly/urban-heat-islands>**

Studies the dependence of an urban heat island on urban geometry using multiyear urban-rural temperature differences and building footprints data. Shows a strong correlation between nocturnal urban heat islands and the city texture. Funded by the Shell/Schlumberger Xshale program and the MIT-CNRS lab, enabled through MITEI.

**Apurba Sakti et al. *Review of wholesale markets and regulations for advanced energy storage services in the United States: Current status and path forward.* September 2018. <http://bit.ly/wholesale-markets>**

Reviews regulations shaping U.S. energy storage deployment and discusses policies for better storage integration with researchers from Argonne National Laboratory. Funded through the Low-Carbon Energy Center for Energy Storage Research.

**Hao Sun et al. *The MIT Green Building benchmark problem for structural health monitoring of tall buildings.* March 2018. <http://bit.ly/mit-green-building>**

Presents a benchmark problem based on data obtained from the MIT Green Building for the structural health monitoring community to study tall buildings. Funded by Shell through MITEI.

**Yogesh Surendranath et al. *Catalytic methane monofunctionalization by an electrogenerated high-valent Pd intermediate.* October 2017. <http://bit.ly/catalytic-methane>**

Develops a new process for converting methane to derivatives of methanol—a key chemical intermediate—and easily transportable drop-in fuel. Establishes methane as a vast natural resource that

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must be better utilized to ease society's transition to a low-carbon energy future. Funded by Eni through MITEI.

**Neal Wadhwa et al. *Motion microscopy for visualizing and quantifying small motions*. October 2017.**

<http://bit.ly/motion-microscopy>

Proposes a new algorithm for amplifying small motions invisible to the naked eye, with applications in the areas of vibration-based infrastructure monitoring. Funded by Shell through MITEI.

## Tata Center for Technology and Design

Now in its sixth year, the [Tata Center for Technology and Design](#) currently supports 47 master's and PhD students who travel abroad at least twice a year to immerse themselves in the social, political, and economic aspects of their research in the developing world. So far, students have worked extensively throughout India, as well as in Nepal, Kenya, Nigeria, Tanzania, Uganda, Rwanda, Brazil, Colombia, and Venezuela. Their experiences abroad inform their ongoing research with the goal of catalyzing positive social impact in the form of policy support and affordable products and services. Through support for these students, and through thoughtfully crafted research projects in the fields of energy, water, the environment, housing, health, and agriculture, the Tata Center advances its mission of bringing technical talent and experience to bear on the challenges of the developing world.

Many Tata students have had noteworthy accomplishments in the past several years. Examples include three Lemelson-MIT awards given to Maher Damak for his work on “sticky agricultural sprays” designed to reduce human exposure to air- and water-borne chemicals; Natasha Wright, for designing solar-powered desalination systems; and Katy Olesnavage for developing a prosthetic foot. Maher Damak and Karim Khalil also won the first prize at the Rice Business Plan Competition for their work in reducing water consumption at power plants. Arun Singh won the 2017 prize for best master's thesis in the Technology and Policy Program, for developing an economic model to inform India's energy and climate policies.

To date, center-funded projects have led to more than 45 patent disclosures to MIT's Technology Licensing Office. Several projects are already on the path to commercialization through startups and licensing arrangements, and many others have attracted follow-on funding from government agencies and commercial sponsors. As projects continue to mature, the Tata Center is developing detailed plans to translate these projects into practice in close cooperation with the Tata Trusts and the Foundation for Innovation and Social Entrepreneurship, a nonprofit incubator established in Bangalore by the Trusts with the government of India.

The Tata Center hosted its third annual Symposium at MIT in 2017. Distinguished guests from India, seasoned entrepreneurs, members of NGOs, as well as vital partners of the Tata Center gathered to discuss the question, “Does the developing world need a new model for entrepreneurship?” Speakers with diverse perspectives on entrepreneurship held panel discussions. The event also featured poster sessions and presentations that introduced guests to the Center's newest projects in agriculture, energy, environment, health, housing, and water.



Wellesley College student Chloe Blazey '19 (left) and her supervisor, Alpha Yacob Arsano, examine a weather station. As a MITEI UROP student, Blazey worked on software that will help architects predict energy consumption for different types of buildings and use that information to reduce the ongoing environmental impact of new buildings. *Photo: Kelley Travers*



During a meeting of her new course Global Energy, Valerie Karplus, the Class of 1943 Career Development Assistant Professor at the MIT Sloan School of Management, leads a class discussion of how stakeholders engaged in political and social processes to help shape the fate of the Cape Wind project in Nantucket Sound. *Photo: Kelley Travers*

## Education

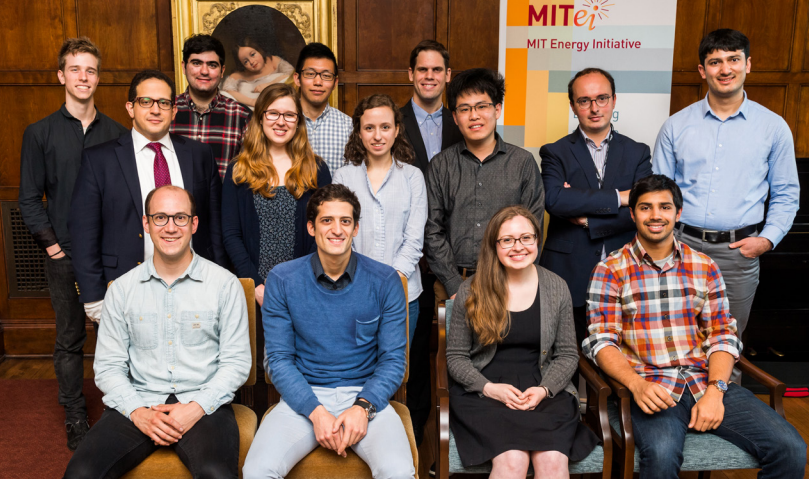
MITEI's role as an educator of future energy change agents is critical to its mission as a catalyst for tomorrow's low-carbon energy solutions. Through programs created for graduate and undergraduate students, MITEI provides a robust educational toolkit to MIT students who want to contribute to the energy transition. These programs allow students to take classes; conduct research in diverse areas, from energy science and social science to technology and engineering; practice their skills; and network with peers and professionals. MIT faculty members work with MITEI's education team to develop the curriculum and act as advisors to aspiring and current energy students.

Students interested in energy at MIT can start as soon as they step onto campus: MITEI runs the Discover Energy Freshman Pre-Orientation Program at the end of the summer before classes begin. The journey continues in the classroom, where undergrads can take interdisciplinary courses through the Energy Studies Minor and participate in laboratory research through the MITEI Undergraduate Research Opportunities Program (UROP).

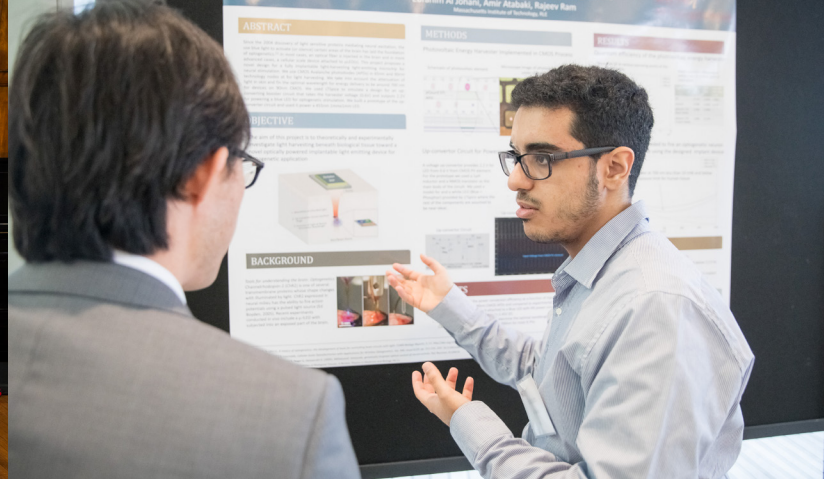
Students participating in the MITEI program Solar Spring Break have the opportunity to immerse themselves in energy practice at GRID Alternatives, a California nonprofit where Anna Bautista '05 (Electrical Engineering and Computer Science) is Vice President of Construction and Workforce Development. For her efforts surrounding workforce diversity and providing technical careers for women, she was honored with the Lifetime Achievement Award for Advocacy at the 2017 symposium of the Clean Energy Education and Empowerment (C3E) Initiative.

Graduate students and postdocs receiving funding from MITEI through the member education fund are an equally important part of the Initiative's energy education ecosystem. In addition to contributing their own research to MITEI's areas of inquiry and collaborating with researchers on white papers and studies, graduate students mentor UROP students and contribute to the development of the Energy Studies Minor curriculum. Through the Society of Energy Fellows, MITEI also hosts activities for graduate student fellows, including dinner meetings with sponsors at MITEI's Annual Research Conference, and a range of informational gatherings and networking events.





The Society of Energy Fellows at MIT welcomed 24 new members in fall 2017. The Energy Fellows network now totals almost 400 graduate students and postdoctoral fellows and spans 20 MIT departments and divisions and all five MIT schools. *Photo: Justin Knight*



At the Annual Research Conference poster session, physics major Ebrahim Al Johani '19 describes his work to develop a small, efficient device that uses infrared light as an energy source to power a small, blue LED. This device could be implemented in chip implants and battery-powered applications that can utilize its miniature, minimally invasive design. *Photo: Bryce Vickmark*

## MITEI Education Program Highlights:

- **Energy Studies Minor:** The Energy Studies Minor Oversight Committee continues to work on several changes to the minor. These updates include improving curriculum flexibility across fall and spring offerings, as well as increasing the number of advisors across academic departments to provide a go-to resource for students planning their course schedules.
- **Undergraduate energy research:** MITEI supported 60 student projects through the MITEI Energy Undergraduate Research Opportunities Program (UROP) during the 2018 academic year, bringing its total number of sponsored projects up to 475, including Tata Center and Center for Energy and Environmental Policy Research projects. This cohort's research spanned a breadth of unique subjects, among them sustainable solutions to the burning of biomass in the developing world, improvements to the comfort conditioning of workspaces, and analysis of how best to commercialize photovoltaic materials for early-stage cleantech startups.
- **Graduate Fellows:** MITEI welcomed 24 new graduate students and postdocs to the Society of Energy Fellows in 2017-2018. The Energy Fellows network now totals almost 400 current and former graduate students and postdoctoral fellows, spanning 20 MIT departments and divisions and all five MIT schools. This year's fellowships are made possible through the generous support of eight MITEI member companies: Bosch, BP, Chevron, Eni S.p.A., ExxonMobil, GE, Shell, and Total.
- **Solar Spring Break:** In March 2018, 11 undergraduate students participated in MITEI's Solar Spring Break program in partnership with nonprofit GRID Alternatives. Over the course of a week, the students installed solar panels on the home of a low-income family in Los Angeles, California. Participants met the homeowner and heard firsthand about the impact of their work, and also attended various other networking and educational events.

- **Textbooks:** *The Physics of Energy*, a new textbook by Professors Robert Jaffe and Washington Taylor, both of the MIT physics department, is now available for purchase. John Heywood, the Sun Jae Professor Emeritus of Mechanical Engineering at MIT, has also completed a second edition of his seminal book, *Internal Combustion Engine Fundamentals*.
- **Freshman Pre-Orientation Program:** The Summer 2017 energy pre-orientation program hosted by MITEI sent 20 freshman students to on- and off-campus locations to learn about opportunities for energy research and education at MIT. Activities included a meeting with representatives from the Institute’s Undergraduate Energy Club, a tour of a wind turbine blade testing facility, a visit to the Fraunhofer Center for Sustainable Energy Systems, and a workshop on building DC motors with Steven Leeb, professor of electrical engineering and computer science and associate director of the Research Laboratory of Electronics.
- **Career Insights Speaker Series:** Energy industry professionals from BlueWave Solar, Embr, and Maxim Integrated visited MITEI to share their career journeys with undergraduates and graduate students.
- **Conversations with energy leaders:** Harry Brekelmans, the projects and technology director for Royal Dutch Shell plc (a MITEI founding member company), met with groups of MIT students and faculty members in September 2017 to discuss their work, before taking part in a [public discussion](#) about energy issues with MITEI Director Robert Armstrong.
- **Annual Research Conference:** At MITEI’s December 2017 Annual Research Conference, 15 undergraduate students presented posters of energy-related work in a wide range of disciplines, from electrochemistry to architecture. The students, all MITEI-sponsored participants in the Undergraduate Research Opportunities Program, had the opportunity to network with energy professionals while showcasing their research.



Harry Brekelmans, the projects and technology director for Royal Dutch Shell plc, meets with groups of MIT students in a morning meeting to discuss carbon pricing, climate change, and long-range R&D planning.  
 Photo: Emily Dahl

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## Energy Education Taskforce

MITEI's Energy Education Task Force (EETF) guides the development of energy education at MIT. Bradford H. Hager, Cecil and Ida Green Professor of Earth Sciences in the Department of Earth, Atmospheric and Planetary Sciences, and Rajeev Ram, professor of electrical engineering and computer science and director of the Research Laboratory of Electronics, serve as the task force's co-chairs. The task force meets regularly throughout the academic year and includes faculty from all five schools at MIT, as well as graduate and undergraduate student representatives. MITEI's education team members support the EETF by implementing energy education programs.

### EETF FACULTY MEMBERS FY2018

**Co-chair: Bradford Hager**, Cecil and Ida Green Professor of Earth Sciences;  
Director, Earth Resources Laboratory

**Co-chair: Rajeev Ram**, Professor of Electrical Engineering and Computer Science; Associate Director,  
Research Laboratory of Electronics

**William H. Green**, Hoyt C. Hottel Professor of Chemical Engineering

**David Hsu**, Assistant Professor of Urban Studies and Planning

**Robert Jaffe**, Jane and Otto Morningstar Professor of Physics

**Ruben Juanes**, ARCO Associate Professor in Energy Studies

**Christopher Knittel**, George P. Shultz Professor of Applied Economics;  
Director, Center for Energy and Environmental Policy Research

**Steven Leeb**, Professor of Electrical Engineering and Computer Science

**Yogesh Surendranath**, Paul M. Cook Career Development Associate Professor of Chemistry

**Konstantin Turitsyn**, Associate Professor of Mechanical Engineering

### EETF STUDENT MEMBER

**Rachel Chava Kurchin** (graduate student), Materials Science and Engineering

## MIT Student Energy Groups

**e4Dev - Energy for Human Development** is a student group and discussion forum on energy and human development challenges in the developing world. e4Dev brings together students, faculty, and practitioners at MIT and beyond who are devoted to working on critical issues at the intersection of energy and the developing world.

**The Edgerton Center** supports numerous undergraduate student clubs and teams researching and designing advanced vehicles and other systems, including the MIT Motorsports team, the MIT Solar Electric Vehicle team, MIT Robotics, and others. Many students on these teams seek out-of-the-classroom technical challenges that come with designing, building, and racing a vehicle using solar and battery-powered energy.

The **Electricity Student Research Group** fosters interdisciplinary energy research by bringing together graduate students who study electric power systems across different courses, divisions, and research centers at MIT and neighboring institutions for regular seminars and discussions on the latest research from across MIT and beyond.

The **MIT Clean Energy Prize (CEP)**, a student-established spinout from the MIT Energy Club, is the world's premier student competition for early-stage energy ventures with the potential to catalyze a new generation of clean energy solutions. The MIT CEP endeavors to inspire and train entrepreneurs to build companies that will significantly accelerate the pace of energy innovation. The competition offers a low-risk, high-reward environment for student entrepreneurs to develop business ideas with the aid of expert mentorship and insightful judging feedback, while gaining exposure to some of the biggest thinkers in the clean energy space. In 2018, the MIT CEP distributed over \$140,000 in prize money to the winning teams across four tracks—generating energy, improving energy usage, delivering energy, and energy for developing economies.

The **MIT Energy Club** is one of the largest student-run organizations at MIT, with over 5,000 members. Its mission is to bring students, professionals, and policymakers together for fact-based analyses of the most pressing challenges in energy. The club holds weekly events, including document-based energy discussion groups and the MIT Energy Lecture Series, alongside signature events such as the annual MIT Energy Night and the MIT Energy Conference. The club's emphasis is on building a community at MIT with a deeper understanding of global energy trends and challenges through open, fact-based discussion.

The **MIT Transportation Club** aims to bring together the campus's transportation community for education, networking, and research collaboration. Founded in spring 2010, the organization has grown rapidly to include over 300 members from across all schools. The MIT Transportation Club is open to any member of the wider MIT community. Key events include a weekly seminar series, tours to transportation centers, and the MIT Transportation Showcase.

The **MIT Undergraduate Association Committee on Sustainability** is charged with being a leading force in sustainability, spreading environmental awareness, and inspiring community action. This committee interfaces with other student advocacy and policy groups, facilitating communication to

induce change. It also identifies and addresses needs within the undergraduate sustainability community, collaborating with faculty and the administration to pull together projects like the Trashion Show and Trash2Treasure.

The **Technology Policy Student Society** is composed of student representatives in the Technology Policy Program who provide opportunities for professional engagement and community building within the TPP cohort and IDSS student body. These include events such as policy discussion nights, student retreats, and speaker series.

The **MIT Water Club** is the leading student network for water research and innovation at MIT. The group organizes annual conferences (Water Summit), research showcases (Water Night), multi-stage entrepreneurship competitions (Water Innovation Prize) and weekly lectures, convening leaders and innovators to explore the most pressing issues in water technology, policy, and science.



The MIT Solar Electric Vehicle Team, a student group working under the auspices of The Edgerton Center, unveils Flux, their car for the 2018 American Solar Challenge. Flux stands apart from previous iterations of the solar car with its asymmetrical body. The driver sits on the same right-hand side as the wheel base, which means there's less drag as it's racing down the road. *Photo: Ivy Pepin*



MIT Energy Initiative Director Robert Armstrong (left) and Former U.S. Secretary of Energy Ernest Moniz discuss the energy sector during a fireside chat at MITEI's Annual Research Conference in 2017. The theme of the 2017 conference was "Energy on the Move," with a focus on decarbonization, digitization, and decentralization of the energy sector. *Photo: Bryce Vickmark*

## Outreach

MITEI's fact-based analysis of current energy topics informs public policy, fosters dialogue within the academic research community, and provides the public with context on vital issues. Convening events throughout the year, MITEI hosts thought leaders from across the energy value chain. MITEI staff, faculty affiliates, and graduate students share their research and perspectives at domestic and international events. Staff members also participate in Institute-wide efforts focused on addressing climate change. MITEI's communications team highlights the research and achievements of faculty and students through articles, media outreach, social media, and other digital and print platforms to reach diverse audiences.

### Outreach Program Highlights

- **MIT Plan for Action on Climate Change:** In January 2018, an ad hoc Climate Action Plan Review Committee submitted a report assessing MIT's progress on its five-year climate action plan and identifying new opportunities for growth. MITEI continues to support these efforts with the ongoing development of its seven Low-Carbon Energy Centers, which are evolving to become more accessible to new types of member companies.
- **Guest speakers:** Leading executives in policy, academia, and industry gave talks at MITEI-hosted events. Speakers included Harry Brekelmans, projects & technology director at Royal Dutch Shell plc; Becca Jones-Albertus, acting deputy director of the U.S. Department of Energy Solar Energy Technologies Office; Norman R. Augustine, retired chairman and CEO of Lockheed Martin Corporation; and others.



Panelist Ugwem Eneyo, co-founder of Solstice Energy Solutions, speaks on a panel at the 2017 C3E Women in Clean Energy Symposium about emerging clean energy technologies. *Photo: Justin Knight*



Abigail Krich, founder and CEO of Boreas Renewables, discusses the incompatibility of New England's electricity market structure with achieving carbon emissions reduction goals during an IHS Seminar. *Photo: Kelley Travers*

- **2017 Annual Research Conference:** Marking 10 years since the inaugural MITEI research conference, the event featured panels offering industry perspectives, faculty research, and undergraduate poster presentations. The conference focused on decarbonization, digitization, and decentralization of the energy sector. Speakers included Agustín Delgado, chief innovation and sustainability officer of Iberdrola S.A.; Eric Gebhardt, vice president of systems and innovation at GE Power; Pratima Rangarajan, CEO of Oil and Gas Climate Initiative Climate Investments; and MIT faculty members.
- **C3E 2017 Women in Clean Energy Symposium:** MITEI hosted the 2017 Clean Energy, Education, and Empowerment (C3E) Women in Clean Energy Symposium and Awards, [\*Transforming Our Energy Infrastructure to Enable the Clean Energy Transition\*](#), in collaboration with the U.S. Department of Energy and the Stanford University Precourt Institute for Energy. The conference featured award presentations to mid-career women and a lifetime achievement award presentation, as well as diverse speakers and rich conversations on strategies and technologies to enable the transition to a low-carbon future. The U.S. C3E Initiative aims to advance clean energy by closing the gender gap and enabling the full participation of women in the clean energy sector.
- **Together in Climate Action—Northeast North America Policy Summit:** On December 7-8, 2017, MIT hosted a summit on climate policy and action in northeastern North America. The summit brought together policymakers, researchers, and industry and nonprofit leaders from New England, New York, Atlantic Canada, and Québec to explore new opportunities for regional collaboration to address climate change. Michael R. Bloomberg, the founder of Bloomberg L.P. and Bloomberg Philanthropies, three-term mayor of New York City, and United Nations Secretary-General's Special Envoy for Cities and Climate Change, delivered the summit's keynote address. MITEI staff provided programming and event logistics support.

- **Caribbean Reconstruction Conference:** At a two-day conference at MIT on December 12-13, 2017, leaders from the Caribbean islands brainstormed with researchers from MIT and elsewhere to develop strategies for not just rebuilding Caribbean islands' extensively damaged infrastructure, but improving its resiliency in the face of the ever-growing threat of powerful hurricanes. The conference was co-hosted by MITEI and the MIT Environmental Solutions Initiative.
- **Support for campus energy events:** MITEI sponsored and provided staff support for numerous campus energy events, including the student-run MIT Energy Conference, the Undergraduate Energy Research Fair, the Energy Career Fair, and the Energy Hackathon. See the **Education** section for more details.

## Events

### MITEI-SPONSORED PUBLIC SEMINARS AND COLLOQUIA, 2017-2018 ACADEMIC YEAR

- September 6, 2017: "If you had a billion dollars for energy-related R&D, where would you spend it?"  
Harry Brekelmans, Projects and Technology Director, Royal Dutch Shell plc
- September 12, 2017: MITEI Special Seminar: "Machine learning applied to fusion research"  
Robert Granetz, MIT Plasma Science and Fusion Center
- October 13, 2017: MIT Energy Night
- October 25, 2017: MITEI Fall Colloquium: "The future of energy: Certain uncertainties"  
Norman R. Augustine, Former chairman and CEO, Lockheed Martin Corporation
- November 3, 2017: MIT Energy Hackathon
- April 10, 2018: MITEI Special Seminar: "U.S.-Mexico natural resource management partnerships:  
Tearing down walls"  
Bruno Verdini, Executive Director, MIT-Harvard Mexico Negotiation Program





At the MIT Conference for the Resilient Reconstruction of the Caribbean, Puerto Rico's governor, Ricardo Rosselló '01 (left), describes the devastation of recent hurricanes and discussed opportunities for collaboration on resilient rebuilding. He is shown in conversation with Robert Stoner, deputy director of the MIT Energy Initiative and director of the Tata Center for Technology and Design.  
*Photo: Justin Knight*



Bruno Verdini (left), executive director of the MIT-Harvard Mexico Negotiation Program, discusses strategies for natural resources negotiation with MITEI Communications Director Emily Dahl at a MITEI seminar. *Photo: Kelley Travers*

## MITEI IHS SEMINAR SERIES, 2017-2018 ACADEMIC YEAR

- October 11, 2017: “What is a petroculture? Conjectures on energy and global culture”  
Imre Szeman, Canada Research Chair, Cultural Studies, University of Alberta; and  
Professor of Communication and Culture, University of Waterloo, Canada
- November 8, 2017: “The potential for solar energy”  
Becca Jones-Albertus, Acting Deputy Director, U.S. Department of Energy, Solar  
Energy Technologies Office
- December 12, 2017: “Achieving the Paris climate goals: The engine of ambition”  
Nate Hultman, Associate Professor, University of Maryland
- February 6, 2018: “Three transportation revolutions: Steering sharing, automation, and  
electrification toward the public interest”  
Daniel Sperling, Professor, University of California, Davis
- March 6, 2018: “Innovating for the clean energy economy”  
Daniel Kammen, Professor, University of California, Berkeley
- April 11, 2018: “New England’s wholesale electricity markets: Incompatible with achieving long-  
term regional emissions reduction goals”  
Abigail Krich, President, Boreas Renewables, LLC
- May 8, 2018: “Passive buildings on the rise: Case studies of multifamily residences that pass  
the test”  
Katrin Klingenberg, Co-founder and Executive Director, Passive House  
Institute US

# Governance



Members of the External Advisory Board at the Fall 2017 meeting of the board. *Photo: Emily Dahl*

## MITEI Leadership Team

Director Robert Armstrong’s leadership team continues to build on MITEI’s strong foundation and bold, multidisciplinary approach to deliver global energy solutions. In addition, the team is broadening MITEI’s membership base, seeking out potential members for the Low-Carbon Energy Centers, increasing opportunities for faculty research, strengthening operations, and playing a lead role in energy education and outreach at MIT.

**Robert C. Armstrong**, Director

**Robert Stoner**, Deputy Director for Technology and Science; Director, Tata Center for Technology and Design

**Martha Broad**, Executive Director

**Louis Carranza**, Associate Director

**Emily Dahl**, Director, Communications

**Antje Danielson**, Director, Education

**Francis O’Sullivan**, Director, Research and Analysis

**Robert Tolu**, Senior Fiscal Officer

## MITEI Energy Council

The Energy Council helps shape MITEI’s research, education, and outreach efforts. Armstrong, Stoner, and Broad are members of the council, which also includes professors Angela Belcher (Biological Engineering and Materials Science and Engineering), John Deutch (Chemistry), Leon Glicksman (Architecture and Mechanical Engineering), Bradford Hager (Earth, Atmospheric, and Planetary Sciences), Christopher Knittel (MIT Sloan), and Yang Shao-Horn (Mechanical Engineering).

### Professor Robert C. Armstrong

Robert C. Armstrong is MITEI’s director and the Chevron Professor of Chemical Engineering. A member of the MIT faculty since 1973, Armstrong served as head of the Department of Chemical Engineering from 1996 to 2007. His research is focused on pathways to a low-carbon energy future.

In 2008, Armstrong was elected into the National Academy of Engineering for conducting outstanding research on non-Newtonian fluid mechanics, co-authoring landmark textbooks, and providing leadership in chemical engineering education. Armstrong received the Warren K. Lewis Award and the Professional Progress Award in 1992, both from the American Institute of Chemical Engineers, and the 2006 Bingham Medal from the Society of Rheology, which is devoted to the study of the science of deformation and flow of matter.

Armstrong was a member of MIT’s *Future of Natural Gas* and *Future of Solar Energy* study groups and is co-chairing the new study on the *Future of Storage*. He co-edited *Game Changers: Energy on the Move* with former U.S. Secretary of State George P. Shultz.

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## **Professor Angela M. Belcher**

Angela Belcher, a member of the MIT faculty since 2001, is the James Mason Crafts Professor of Biological Engineering and Materials Science. Belcher is a materials chemist with expertise in biomaterials, biomolecular materials, organic-inorganic interfaces, and solid-state chemistry. Her work focuses on evolving organisms to build new materials and devices for clean energy, electronics, the environment, and medicine. She is the co-director of MITEI's Low-Carbon Energy Center for Energy Bioscience. Belcher was awarded the 24th annual MacArthur Foundation Fellowship, the 2013 MIT-Lemelson Prize, the 2010 Eni Prize for Renewable and Non-conventional Energy, and the 2004 Four Star General Recognition Award. In 2006, she was named *Scientific American's* Research Leader of the Year. She was inducted into the National Academy of Inventors in 2015 and the National Academy of Engineers in 2018.

## **Martha Broad**

Martha Broad, MITEI's executive director, oversees MITEI's finance, operations, communications, and events teams that support MITEI's research, education, and outreach activities. In addition, as a member of MITEI's leadership team, she plays a key role in managing the ongoing development of MITEI's Low-Carbon Energy Centers. She has represented MITEI as an invited speaker at Chatham House's Energy Transitions Conference, ARPA-E's Energy Innovation Summit, the MIT Energy Conference, and other events. She served on MIT's Climate Action Advisory Committee for implementing the Institute's Plan for Action on Climate Change. She also served on the World Economic Forum's Global Agenda Council on Decarbonizing Energy.

In addition, she spearheads MITEI's collaboration with the U.S. Department of Energy to design, manage, and host the annual Clean Energy, Education, and Empowerment (C3E) Women in Clean Energy Symposium, and serves as a C3E Ambassador.

Previously, as part of the senior management team of the Massachusetts Clean Energy Center (MassCEC), Broad led programs and studies that focused on the commercialization of clean energy technologies. By collaborating with universities and public and private partners, she helped facilitate the state's successful installation of hundreds of megawatts of wind and solar systems.

## **Professor John M. Deutch**

John Deutch, Institute Professor Emeritus, joined the MIT faculty in 1970. He served as chairman of the Department of Chemistry, Dean of Science, and Provost. Deutch was instrumental in the creation of MITEI's "Future of" series and has published widely in the area of physical chemistry as well as on technology, energy, international security, and public policy issues. Deutch served in the U.S. Department of Energy as director of energy research and undersecretary of the department in the Carter Administration and as undersecretary for acquisition and technology, deputy secretary of defense, and director of central intelligence in the first Clinton Administration. In 2009, Deutch was appointed to the Secretary of Energy Advisory Board (SEAB), the independent 19-member advisory board comprised of scientists, business executives, academics, and former government officials, in which he served under former U.S. Secretaries of Energy Steven Chu and Ernest Moniz.

**Professor Leon R. Glicksman**

Leon Glicksman is a professor emeritus of building technology and mechanical engineering, a member of the MIT faculty since 1966, and the director of MIT's Building Technology Program for 19 years. His research focuses on energy-efficient, sustainable building technologies and designs, including natural ventilation, software design tools, and the integration of energy-efficient measures with indoor air quality considerations. He is an expert on energy-efficient urban housing for the developing world with ongoing projects in India, Nepal, and China.

**Professor Bradford H. Hager**

Brad Hager is the Cecil and Ida Green Professor of Earth Sciences at MIT. He earned his PhD from Harvard University in 1978, began his career as a professor at Caltech's Seismological Laboratory, and joined MIT in 1989. He is the co-director of MITEI's Low-Carbon Energy Center for Carbon Capture, Utilization, and Storage and a member of the Energy Education Task Force. From June 2012 through April 2018, he was the director of MIT's Earth Resources Laboratory (ERL) and now serves as associate director. Hager's research interests include the relationship among space-geodetic observations of surface deformation, earthquakes, and dynamical processes in Earth's interior. He has expertise on tectonic earthquakes in regional fault systems, as well as deformation and earthquakes induced by fluid injection and reservoir production. Hager is on NASA's NISAR Science Definition Team, providing input on earthquake, hydrocarbon, carbon sequestration, and hydrologic applications. He is a Fellow of the American Geophysical Union and the American Academy of Arts and Sciences. He has been awarded the Macelwane and Lehmann Medals by the American Geophysical Union, the Woollard Award by the Geological Society of America, and the Augustus Love Medal by the European Geophysical Union.

**Professor Christopher Knittel**

Christopher Knittel is the George P. Shultz Professor of Applied Economics in the Sloan School of Management and the director of the Center for Energy and Environmental Policy Research (CEEPR) at MIT. He joined the faculty at MIT in 2011, having taught previously at UC Davis and Boston University. Knittel co-led MITEI's *Utility of the Future* study and serves on the Energy Education Task Force and Energy Minor Oversight Committee. He is also co-director of MITEI's Low-Carbon Energy Center for Electric Power Systems.

Knittel's research focuses on environmental economics, industrial organization, and applied econometrics. He is a research associate at the National Bureau of Economic Research in the productivity, industrial organization, and energy and environmental economics groups.

**Robert Stoner**

Robert Stoner is MITEI's deputy director for science and technology. He is also the founding director of the Tata Center for Technology and Design—an MIT graduate program that trains future engineering and business leaders to apply science and technology to the needs and opportunities in the developing world. His current research involves planning and optimization of electrical power systems.

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He is the inventor of numerous optical and electronic devices and has an extensive international business background, having held senior positions at Intel and Zygo Corporations and founded technology companies in the United States and Europe. He earned his PhD in condensed matter physics at Brown University and was an adjunct professor of engineering there from 1995 through 2002. Immediately prior to joining MIT, he served in senior roles at the Clinton Foundation in Africa and India.

### **Professor Yang Shao-Horn**

Yang Shao-Horn is W.M. Keck Professor of Energy at MIT. Her research focuses on the chemical physics of surfaces with emphasis on metal oxides, searching for descriptors of catalytic activity, wetting properties and ion transport, and design materials for solar fuel and batteries including electrochemical/photoelectrochemical water splitting and CO<sub>2</sub> reduction, ion/electron storage, and ion conductors. Shao-Horn is a member of the National Academy of Engineering and was listed in Thomson Reuter’s “World’s Most Influential Scientific Minds” and ranked in their list of “Highly Cited Researchers.” She is also a fellow of the Electrochemical Society and International Society of Electrochemistry.

## **External Advisory Board**

An External Advisory Board composed of industry, academic, nonprofit, and public sector leaders—chaired by former U.S. Secretary of State George Shultz—provides oversight to the Initiative. The views and guidance of the board greatly assist MITEI in maximizing its impact in helping to meet the world’s energy needs, reduce the environmental impacts of energy production and consumption, and inform public discourse on energy and the environment. The board meets annually each fall.

## **Energy Education Task Force**

The Energy Education Task Force, composed of faculty members and students from all five of MIT’s schools, oversees the Initiative’s Education program. Task Force members develop new directions and support activities in this realm of opportunity at MIT. (See the **Education** section for full details).

## **MITEI Members**

MITEI’s members are critical in the energy innovation chain, linking MIT’s world-class research teams with innovators in industry and government to address pressing energy challenges and move solutions into the marketplace. Along with delivering valuable industry perspectives on current technology challenges, members offer research opportunities and critical funding for next-generation energy technologies.

MITEI draws on MIT’s research capabilities, innovation, expertise, and experience to create successful industry collaborations to meet its research partners’ key strategic objectives. A multi-tiered membership structure enables private-sector partners to sponsor multidisciplinary “flagship” research programs with MIT faculty; contribute to energy-focused labs, programs, and centers at MIT; fund critical energy

fellowships; support innovative energy concepts from proposals solicited across the campus; and participate in MITEI's seminars, lectures, and colloquia.

MITEI's Low-Carbon Energy Centers offer a “commons” approach, multiplying benefits for participating members. With the opportunity to pool resources and increase the overall understanding of research and analysis for their organization, each member benefits individually and contributes to the collaborative effort.

## MEMBER HIGHLIGHTS

This year, MITEI's members helped facilitate huge strides in fusion, undergraduate energy education, and the global energy transition.

- New Low-Carbon Energy Center members in FY2018 include: Chevron, Citizens Utility Board, Duke Energy, Engie, Environmental Defense Fund, [IHI Corporation](#), [Magnolia Quality Development Corporation Limited \(MQDC\)](#), and National Grid. These new Center members include companies that are expanding on their current MITEI memberships and others that are joining MITEI as first-time members.
- MITEI helped facilitate a new, first-of-its kind collaboration to move the carbon-free promise of fusion power closer to reality. As [announced in March 2018](#), Italian energy company Eni S.p.A., a founding member of MITEI, has committed to funding a new private company founded and run by former MIT staff and students: Commonwealth Fusion Systems (CFS). CFS will use some of the funding to support MIT fusion research efforts. Eni is also supporting fusion research projects through the MIT Plasma Science and Fusion Center's newly created Laboratory for Innovation in Fusion Technologies. The goal of this collaboration is to advance research that could enable fusion energy to reach commercialization within the next 15 years.
- MITEI has developed a new membership category specifically designated for energy startups. The aim is to accelerate the commercialization of new low-carbon technologies by both forging connections between these entrepreneurial companies and more established energy companies, and providing these startups access to talent and facilities at MIT. Commonwealth Fusion Systems is the first Startup Member.
- An agreement between [Saudi Aramco](#) and MITEI, signed at the MIT-hosted “Innovation to Impact” forum in March, establishes a new five-year collaboration to develop breakthrough solutions for global energy and climate challenges. The funds will support wide-ranging areas of research, including sustainable and renewable energy; carbon capture, utilization, and storage; environmental sciences; energy storage; water conservation and reuse; advanced materials; and computational modeling, artificial intelligence, robotics, and nanotechnologies.
- In partnership with the MIT International Science and Technology Initiatives, eight MIT undergraduates interned abroad in summer 2017 with MITEI member companies: six at Shell in India, one at Shell in Germany, and one at Iberdrola in Spain. During their [internships](#), students were given opportunities to work on a wide range of energy projects, from analyzing fuel additives to evaluating how new technologies might transform energy markets.

A complete list of members is available on the [MITEI website](#).



# Affiliated Groups



Michael Mehling, deputy director of MIT's Center for Energy and Environmental Policy Research, discusses cross-border climate collaboration for mutual gains at a COP23 side event on the role of trade policy in aiding implementation of the Paris Agreement, held by Climate Strategies, a network of researchers, and the German Development Institute. *Photo: Emily Dahl*

MITEI is affiliated with faculty members in a number of MIT centers, departments, and laboratories pursuing interdisciplinary energy and environmental activities. MITEI supports the financial administration of certain projects and collaborates on research and education activities with these organizations.

## Center for Energy and Environmental Policy Research

Established in 1977, the Center for Energy and Environmental Policy Research (CEEPR) promotes research on energy and environmental policy to support improved decision making by government and industry. It is directed by Professor Christopher Knittel (MIT Sloan) and jointly sponsored by MITEI, the Department of Economics, and the MIT Sloan School of Management.

Affiliated faculty and research staff as well as international research associates contribute to empirical research on policy issues related to coal, oil, gas, and electricity markets; nuclear power; transport; energy infrastructure; investment finance and risk management; and environmental and carbon constraints. CEEPR cooperates closely with associates in government and industry from around the globe to enhance the relevance of its research.

CEEPR produces working papers and policy briefs, and provides research input to larger, interdisciplinary studies. It holds two annual research workshops in Cambridge, Massachusetts and a European energy policy conference organized jointly with the Energy Policy Research Group at the University of Cambridge in the U.K.

The E2e project is a collaborative project initiated by Knittel, former MIT Professor Michael Greenstone (now at the University of Chicago), and Professor Catherine Wolfram of the University of California, Berkeley, to leverage cutting-edge scientific and economic insights on the causes of the persistent energy efficiency gap. E2e focuses these talents on solving one of the most perplexing energy questions today and communicating those findings to policymakers and the public. E2e's research generates rigorous and accurate evaluations of energy-efficiency technologies and programs using state-of-the-art empirical methodologies.

## Joint Program on the Science and Policy of Global Change

Led by co-directors Professor Ronald G. Prinn (EAPS) and John Reilly (MIT Sloan), the Joint Program's integrated team of natural and social scientists studies the interactions among human and Earth systems to provide a sound foundation of scientific knowledge to aid decision-makers in confronting interwoven challenges including future food, energy, water, climate, and air pollution, and other challenges.

This mission is accomplished through:

- Quantitative analyses of global changes and their social and environmental implications, achieved by employing and constantly improving an Integrated Global System Modeling (IGSM) framework;
- Independent assessments of potential responses to global risks through mitigation and adaptation measures;

- Outreach efforts to analysis groups, policymaking communities, and the public; and
- The cultivation of a new generation of researchers with the skills to tackle complex global challenges in the future.

Building on the twin pillars of science and policy, the program was founded in 1991 as a joint effort of two distinct groups: the MIT Center for Global Change Science (CGCS) and the MIT Center for Energy and Environmental Policy Research (CEEPR).

## MultiScale Materials Science for Energy and Environment Laboratory

MITEI continues to host the MultiScale Materials Science for Energy and Environment Laboratory, an international joint unit (UMI) between France's National Center for Scientific Research ([CNRS](#)) and MIT at the center of a strategic association covering research, training, and education in partnership with industry. The UMI aims at "bottom-up" simulation and experimental verification of properties of complex multiscale materials—from atomic-scale to microns, and from nanoseconds to years. Materials with important technological, economic, energy, and environmental applications are addressed, including cement, ceramics, nuclear fuels, steels, and geo-materials. The UMI hosts French researchers at MIT, each for multiple years, and is seen as a gateway to further collaboration between CNRS and MIT. The UMI, which is housed at MIT under the auspices of MITEI, has been designated by the CNRS as the lead unit of an international research network consisting of multiple institutions engaged in materials science in the U.S. as well as in Europe.

## Office of Sustainability

The mission of the Office of Sustainability (MITOS) is to transform MIT into a powerful model that generates new and proven ways of responding to the unprecedented challenges of a changing planet via operational excellence, education, research, and innovation on campus. Established in 2013 under the Executive Vice President and Treasurer's Office, MITOS works to integrate sustainability across all levels of campus by engaging the collective brainpower of students, staff, faculty, alumni, and partners. MITOS has set out to have an impact across scales, from the individual to the global.

MITEI staff and faculty affiliates collaborate with the Office of Sustainability through initiatives such as the Campus Sustainability Task Force, living lab projects, and the MIT Climate Action Advisory Committee.

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