

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, including 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 policymakers and regulators, such as the "Future of..." study series, including [The Future of Solar Energy](#) (2015) and a study currently under way, [The Future of Nuclear Energy in a Carbon-Constrained World](#), with the Department of Nuclear Science and Engineering. Other studies include systems-level research such as the 2016 [Utility of the Future](#) study and report and a new study under development: [Mobility of the Future](#).

As a vital component of MIT's [Plan for Action on Climate Change](#), MITEI's eight 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, fusion, and other areas.

MITEI leads the Institute's energy education efforts and has engaged thousands of undergraduate, graduate, and postdoctoral students through sponsored research opportunities and other programs. Energy education programs include the energy studies minor, the Undergraduate Research Opportunities Program (UROP) in energy, short modules during the Independent Activities Period, an energy-focused freshman pre-orientation program, the 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.

In addition to informing public policy through research reports, MITEI's comprehensive outreach efforts foster dialogue within the academic research community and provide the public with context on current energy issues. To facilitate this exchange of information, MITEI hosts and sponsors events on campus, and also supports faculty and staff participation in external events. Using print and digital platforms, as well as media outreach, MITEI develops content to highlight MIT energy researchers and students and share news about their work.

Accomplishments and Updates

Low-Carbon Energy Centers

Since unveiling the Low-Carbon Energy Centers in autumn 2015 as part of MIT's Plan for Action on Climate Change, MITEI has continued to develop a suite of eight research centers dedicated to advancing key technology areas for addressing climate change. Each of the eight 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; fusion and magnets; and solar energy.

With challenges as complex and vast as addressing climate change while meeting growing global energy needs, experts across all disciplines and sectors need to be engaged. Through the Low-Carbon Energy Centers, MITEI is facilitating this vital 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.

MITEI has made significant progress in attracting current members to participate in the centers—in addition to their existing commitments to MIT. It is also clear that this model is attractive to companies such as investor-owned utilities, which, while large in size and market capitalization, do not generally have a history of sponsoring research at universities.

MIT researchers, in collaboration with center members, will continue to forge the path to a decarbonized energy future by developing and scaling the technologies that result from these growing collaborations.

New Center Members

Since the release of the climate plan, MITEI has generated \$54 million in sponsored research activity related to the Low-Carbon Energy Centers. To date, 10 MITEI members have committed support for the centers—with some members supporting multiple centers—and interest continues to grow. Member highlights from FY2017 include the following:

- Canadian integrated oil company Cenovus Energy joined MITEI in February 2017 with a three-year membership that includes participation in the Center for Carbon Capture, Utilization, and Storage (CCUS).
- In January 2017, MIT president Rafael Reif and Eni S.p.A. CEO Claudio Descalzi met in Rome to renew the nine-year collaboration between the Institute and the Italian energy company for another four years. The \$20 million agreement includes an extension of Eni's founding membership in MITEI and research support for the Center for Solar Energy Research, the Center for Energy Storage Research, and CCUS.
- The ENN Group of China, one of China's largest private energy companies, committed to a three-year membership in order to participate in the Center for Energy Storage Research, recognizing the critical need for scalable energy storage solutions to develop regional energy systems.

- In October 2016, MITEI announced that ExxonMobil was expanding its support for MITEI's research and development of low-carbon technologies, building on the company's 2014 commitment as a founding member of MITEI. ExxonMobil joined CCUS.
- GE joined MITEI as a sustaining member in August 2016. GE has committed a total of \$7.5 million over a five-year period to support low-carbon energy research. The company is participating in four centers: Solar Energy Research, Energy Storage Research, Electric Power Systems Research, and CCUS.
- Global power company Iberdrola renewed and significantly expanded its collaboration with MITEI with a \$10.3 million agreement, as announced by President Reif and Iberdrola chairman and CEO Ignacio S. Galán in June 2017. Iberdrola became an MITEI sustaining member, joining the Center for Electric Power Systems Research as a part of this membership. The agreement includes \$5 million in funding for the Iberdrola-AVANGRID Professorship in Power Systems Engineering.
- MITEI founding member Saudi Aramco joined CCUS and the Center for Materials in Energy and Extreme Environments.
- Statoil, a current MITEI sustaining member, joined three centers: CCUS, Energy Storage Research, and Solar Energy Research.

Workshops and Presentations

MITEI director of research Francis O'Sullivan and his team of postdoctoral researchers have made multiple presentations for members of the Center for Energy Storage Research and CCUS regarding the technological and economic challenges and opportunities associated with these technologies. CCUS co-directors Alan Hatton and Brad Hager, along with Executive Director Howard Herzog, have held two workshops to discuss research projects. Other centers are in the process of planning events for FY2018.

Annual Research Conference

At MITEI's annual research conference in October 2016, the center directors gathered to share their work to date and their plans for the future with an audience of MITEI member companies and other guests. Jeffrey Grossman, professor of materials science and engineering and co-director of the Center for Energy Storage Research, noted that the feedback he has received from the more than 30 MIT faculty members who are already involved in the centers shows that "they couldn't be happier and more excited about the centers. They want to work on what's relevant—things that are really going to make a difference. The only way to do that is to work with industry and to do this really deep dive on the powerful combination of technical and economic analysis."

Research

MITEI's core mission is to enable the low-carbon economy of the future through the creation of renewable energy, energy efficiency, and carbon management technologies, and its research portfolio reflects this goal. 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 more than 900 projects to date, many involving collaboration between MIT researchers and member researchers. Approximately 30% of MIT faculty members have engaged with MITEI's programs.

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 \$150,000 to each of 10 early-stage MIT energy research projects, for a total of \$1.5 million. Including the 2017 grants, MITEI has supported 161 energy-focused projects with grants totaling \$21.4 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: MITEI published its Utility of the Future report, based on a multi-year study, and announced the launch of the Mobility of the Future study. This study is exploring how consumers and markets will respond to potentially disruptive technologies, business models, and government policies in the transportation sector. Also, as noted above, the eighth study in MITEI's "Future of..." series, The Future of Nuclear Energy in a Carbon-Constrained World, is under way within the Department of Nuclear Science and Engineering. More details on each of these studies are provided in the consortium research section.

Working papers: The Institute released working papers written by MITEI staff, faculty affiliates, and graduate students on subjects ranging from cybersecurity to support for renewable energy policies.

National research consortium participation: The US Department of Energy announced MITEI as one of the members of the new Rapid Advancement in Process Intensification Deployment (RAPID) Manufacturing Institute, the 10th institute in the national network of Manufacturing USA Institutes. MITEI faculty affiliates are contributing clean energy expertise to this public-private coalition that will address manufacturing challenges in energy-intensive processing industries. MITEI is also sharing faculty expertise in clean energy innovation as an academic and research collaborator in the Smart Manufacturing Leadership Coalition, announced by former president Barack Obama in June 2016; this coalition will lead the new Smart Manufacturing Innovation Institute in developing smart technologies and systems for use in advanced manufacturing.

Faculty Research Highlights

Energy Storage

New lithium-oxygen battery: Ju Li, the Battelle Energy Alliance Professor of Nuclear Science and Engineering; postdoc Zhi Zhu; and a joint team from MIT, the Argonne National Laboratory, and Peking University in China found a way to alter the chemistry of lithium-oxygen batteries that greatly improves energy efficiency and longevity and overcomes key drawbacks of previous versions of lithium-air batteries.

Nuclear Energy

The Future of Nuclear Energy in a Carbon-Constrained World: Research is under way on a new study that aims to identify prospects for innovative nuclear technologies, policy and business models, and regulatory governance mechanisms to accelerate the transition to a lower-carbon global energy system.

New record for fusion: On September 30, 2016, on its last day of operation, the Alcator C-Mod tokamak nuclear fusion reactor set a new world record for plasma pressure. Plasma pressure is the key ingredient in producing energy from nuclear fusion, making the record a huge leap forward in the pursuit of clean energy.

Transportation

Mobility of the Future study: MITEI's Mobility of the Future study examines how developments in technology, fuel, infrastructure, policy, and consumer preference will drive changes in future transportation.

Data-driven approach to pavement management: Concrete Sustainability Hub (CSHub) researchers Arghavan Louhghalam, Mehdi Akbarian, and Franz-Josef Ulm, the CSHub faculty director, introduced a new way to reduce emissions across roadway networks by using big data to identify specific pavement sections where improvements will have the greatest impact.

Electric vehicles and climate change: A study from Jessika Trancik, the Atlantic Richfield Career Development Associate Professor in Energy Studies, and her team at MIT showed that a wholesale replacement of conventional vehicles with electric ones is possible today and could play a significant role in meeting climate change mitigation goals.

Electric Power Systems

Guidance for the evolving electric power sector: MITEI's Utility of the Future study calls for regulatory, policy, and market overhauls in the changing electric power sector.

Efficient power converter for the Internet of Things: Researchers from MIT's Microsystems Technology Laboratories, including former postdoc Arun Paidimarri and thesis advisor Anantha Chandrakasan, dean of the School of Engineering and Vannevar Bush Professor of Electrical Engineering and Computer Science, designed a new power converter that maintains its efficiency at currents ranging from 100 picoamps to 1 milliamp, a span that encompasses a million-fold increase in current levels. The converter is ideal for the diverse electricity needs related to the Internet of Things.

Clean power planning: A study from the MIT Joint Program on the Science and Policy of Global Change, led by research scientist Jennifer Morris, detailed why it makes sense to invest in carbon-free energy now, determining that the optimal electricity sector investment for the next decade would allocate 20% to 30% of new generation to non-carbon sources.

Materials Science

Converting carbon dioxide to fuels: MIT chemists demonstrated major advances in the design of a device that could one day take carbon dioxide emissions from fossil fuel combustion and—powered by renewable energy—turn them back into high-quality fuels.

Better catalysts for energy storage devices: Experimental and theoretical studies performed by MIT researchers provided a new understanding of why certain catalysts are so effective at encouraging the release of oxygen from water during electrolysis, a key process in many energy storage devices.

New metal-producing method developed: Donald Sadoway, the John F. Elliott Professor of Materials Chemistry, and his team at MIT discovered a new way of producing the metal antimony that could potentially lead to new techniques for smelting other metals as well. The group found that by using electricity instead of heat during the process, they could virtually eliminate the greenhouse gas emissions associated with traditional smelting and reduce energy costs.

Solar Energy

Graphene electrodes and transparent, flexible solar cells: Professor Jing Kong and graduate student Yi Song of the Department of Electrical Engineering and Computer Science fabricated one-atom-thick graphene electrodes and then—using a novel technique—transferred them onto flexible, transparent solar cells that they can mount on surfaces ranging from glass and plastic to paper and tape.

Ultra-light, ultra-thin solar cells: Professor Vladimir Bulović is working to develop ultra-light and ultra-thin solar cells that could be used to power electronic devices and could eventually be scaled to power buildings. To date, he and his team have developed the thinnest, lightest solar cells ever produced.

Detecting defects that reduce solar cell efficiency: Tonio Buonassisi, associate professor of mechanical engineering, postdoc Ashley Morishige, and graduate student Mallory Jensen pinpointed certain manufacturing processes and material impurities that could be the reason why specific types of solar cells lose productivity after just a few months.

Energy and Climate Economics and Policy

More aggressive measures to limit global warming: Researchers from the MIT Joint Program on the Science and Policy of Global Change analyzed the Paris climate agreement and laid out the additional measures that must be taken to avoid exceeding the 2°C maximum target.

Modeling the unequal benefits of US environmental policy: MIT Joint Program researchers provided the first breakdown of ozone exposure, health, and economic impacts by household income across the United States.

Strengthening public support for renewable energy policies: Associate Professor of Political Science Christopher Warshaw and Leah Stokes SM '15, PhD '15, examined the interaction between public opinion and renewable energy policy-making.

Aggressive policy action to move away from fossil fuel energy: Christopher Knittel, the George P. Shultz Professor of Applied Economics in the MIT Sloan School of Management, and his collaborators Michael Greenstone and Thomas Covert of the University of Chicago examined historical and predicted costs for fossil fuel resources and carbon-free energy technologies and concluded that if the world is to cut greenhouse gas emissions enough to avert a disastrous temperature rise, policymakers must put a price on carbon emissions and invest heavily in research and development to improve low-carbon energy technologies.

Additional Low-Carbon Energy Research

Liquid tin-sulfur compound: MITEI Seed Fund Program grant recipients Antoine Allanore, assistant professor of metallurgy; Cooper Rinzler, PhD '17; and graduate student Youyang Zhao created a high-temperature tin-sulfur device that produced electricity from industrial waste heat.

Microbial engineering: A new microbial engineering technique created by Gregory Stephanopoulos, the Willard Henry Dow Professor of Chemical Engineering and Biotechnology, and his team could reduce the cost and environmental impact of producing liquid biofuels and biochemicals as alternatives to petroleum-based products.

Energy-efficient design: Caitlin Mueller, assistant professor of architecture and civil and environmental engineering, and PhD candidate Nathan Brown have designed a computer simulation that can help architects optimize energy consumption by examining variables among potential building structures early in the design process.

Energy in the Developing World

Tackling air pollution in China: A study led by Paul Natsuo Kishimoto, a PhD candidate in the Institute for Data, Systems, and Society; Valerie Karplus, assistant professor of global economics and management in the Sloan School of Management; and a team of researchers from MIT, Tsinghua University, and Emory University considered how effective new measures will be in reducing China's air pollution, determining that the country must make considerable changes to industry and transportation.

Metal-organic framework for adsorption cooling: Associate Professor of Chemistry Mircea Dincă has developed a new kind of sponge-like metal organic framework capable of capturing moisture with unprecedented efficiency from relatively dry air. Potential uses include point-of-use fresh water production in arid environments and energy-efficient cooling for air conditioning and food preservation.

Combined energy and water system: Professor of Mechanical Engineering Alexander Slocum and his colleagues—Maha Haji, Sasan Ghaemsaïdi, and Marco Ferrara of MIT—developed a detailed engineering, geographic, and economic model of a combined pumped hydropower energy storage system and a reverse osmosis desalination plant that could be used in highly populated coastal regions that suffer from severe droughts.

Quest for clean water: Assistant Professor of Mechanical Engineering Amos Winter and PhD candidate Natasha Wright, a Tata Center for Technology and Design Fellow, have

designed a solar-powered desalination system for use in rural India with support from the Indian engineering firm Tata Projects, which hopes to bring a version of the system to market. This is an outcome of the team's successful research program initiated with the support of the Tata Center.

Community-scale power: Robert Stoner, MITEI deputy director for science and technology and the director of the Tata Center, and Ignacio Pérez-Arriaga, an MITEI visiting professor from Universidad Pontificia Comillas in Spain, used their reference electrification model to identify an off-grid community in Bihar, India. They designed a community-scale power system—a microgrid—that was subsequently built and commissioned by GE and Tata Power DDL. They are now working with GE and the World Bank on a larger-scale effort in three states of Nigeria focused on identifying economic off-grid communities as candidates for electrification with World Bank funds.

MITEI Consortium Research

Utility of the Future Study

The Utility of the Future study report, released in December 2016, was the result of a multi-year effort that examined the technology, policy, and business models shaping the evolution of the delivery of electricity services in the United States, Europe, and other parts of the world. The report recommended proactive reforms to ensure that both distributed and centralized energy resources are integrated efficiently in the shift toward a low-carbon energy future.

In a news release accompanying the report, study executive director Raanan Miller said, “This report is the result of a multiyear, comprehensive, and rigorous research study in which authors conducted extensive primary research, including data gathering and modeling, and interviews with regulators and business leaders in the electric power sector—including the study consortium members. We hope that regulators, policymakers, and industry stakeholders find it a useful source of information that helps them weigh decisions and take actions to guide the evolution of the electric power sector.”

The report, which was developed in collaboration with the Institute for Research in Technology at Comillas Pontifical University, will inform research conducted through MITEI's Center for Electric Power Systems Research, one of the eight Low-Carbon Energy Centers. The consortium of study members consists of a diverse group of leading international companies and organizations.

Mobility of the Future Study

In December 2016, MITEI publicly announced the launch of the multidisciplinary Mobility of the Future study to explore 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.

“It is well recognized that transportation is the most challenging economic sector to decarbonize,” said MITEI director Robert Armstrong in the study announcement. “Our three-year Mobility of the Future study is tackling complex questions of how technology advances, consumer choice, new business models, and government policies could change the trajectory of mobility to fundamentally alter the carbon intensity of the future transportation system.”

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

Future of Nuclear Energy in a Carbon-Constrained World

This year Department of Nuclear Science and Engineering professor Jacopo Buongiorno, who leads the Low-Carbon Energy Center for Advanced Nuclear Energy Systems, announced the multidisciplinary Future of Nuclear Energy in a Carbon-Constrained World study, the eighth in MITEI’s “Future of...” report series. Buongiorno’s team consists of seven MIT faculty members from across the Institute as well as two Harvard University faculty members and four external consultants. The goal of the study is to conduct an objective assessment of the opportunities and challenges affecting the ability of nuclear energy technologies to meet US and global energy needs in a carbon-constrained world.

Tata Center for Technology and Design

Now at the end of its fifth year, the Tata Center for Technology and Design supports 65 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, Uganda, and Rwanda. Their experiences abroad inform their ongoing research with the goal of catalyzing positive social impacts 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 had noteworthy accomplishments this year. Examples include Natasha Wright, who won the prestigious Lemelson-MIT Prize for her work designing solar-powered desalination systems, and Maher Damak, who won the World Technology Award in the Environment category and the MIT Clean Energy Prize for his work on reducing water consumption at power plants in water-stressed regions. Damak also won the Rabobank Food and Agribusiness Prize for his work on “sticky agricultural sprays” designed to reduce human exposure to airborne and waterborne chemicals. In the area of policy, Arun Singh represented MIT at the 2016 United Nations Climate Change Conference (COP 22) in Marrakech, Morocco, presenting his research on an economic model to inform India’s energy and climate policies. His thesis on that topic was named the best thesis of 2017 by the MIT Technology and Policy Program.

To date, center-funded projects have led to more than 30 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 working to develop detailed plans for translation to practice in close cooperation with the Tata Trusts and the Foundation for Innovation and Social Entrepreneurship (FISE), a nonprofit incubator established this year in Bangalore by the Trusts with the government of India. FISE is a key building block of Social Alpha, a novel business and social enterprise incubation and investment platform designed to foster socially oriented business creation in India. Complementing this initiative, the Tata Center is leading an effort within MIT to leverage existing programs in entrepreneurship, business mentoring, and acceleration to train students.

To support its expanding translational research activities, the Tata Trusts increased its original funding commitment to the Tata Center by \$16 million in May 2016. The Trusts further committed \$15 million over five years to support "Grid Edge," an ambitious program under Professor Vladimir Bulović to develop low-cost printed solar modules for rural electrification. The Tata Center recently hired a new director of translational research to spearhead these efforts in the coming years.

The second annual Tata Center Symposium at MIT, held in fall 2016, attracted hundreds of attendees and brought the MIT community and members of India's business, government, nonprofit, and philanthropic communities together to explore new challenges and expand the center's global partner network. In 2017, the event will expand to include a research conference, making it both a forum for discussion of major developing world issues and a showcase of MIT's rigorous application of technology and design in resource-constrained communities.

Education

MITEI's role as an educator of future energy leaders 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 toolkit for MIT students to complete a robust multidisciplinary energy education, taking classes and conducting research that covers diverse areas ranging from energy science and social science to technology and engineering. MIT faculty members work with MITEI's education team to develop this curriculum and act as mentors and role models for aspiring and current energy students.

Students at MIT interested in energy can start as soon as they step onto campus: MITEI runs the Discover Energy Freshman Pre-Orientation Program for accepted MIT students in the summer before their first classes. The journey continues in the classroom, where undergraduates can take interdisciplinary courses through the energy studies minor, established by MITEI in 2009, and participate in the energy Undergraduate Research Opportunities Program during the year or over the summer.

Graduate students and postdocs hosted at MITEI through the member-supported Society of Energy Fellows are an equally important part of the initiative's energy innovation and 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 spend time mentoring UROP students and contributing to the

development of the energy studies minor curriculum. MITEI also hosts activities for the fellows, including dinner meetings with sponsors at MITEI's annual research conference and a range of informational gatherings.

Selected education program highlights are listed below.

Energy and climate change curriculum development: With support from members and donors, MITEI has invested \$1.5 million in energy and climate change education and curriculum development at MIT. A significant grant from the S.D. Bechtel, Jr. Foundation has been essential in supporting these efforts.

Energy studies minor: The energy studies minor oversight committee held meetings to discuss redesigning, streamlining, and expanding the curriculum for the minor. The plan for executing these changes is expected to take effect in AY2019.

New energy courses: As part of the expansion of the minor, a group of new energy courses was developed and offered for the first time last year to students at MIT studying energy. The courses, all of which are eligible for credit toward the minor, are as follows: 2.603 Fundamentals of Smart and Resilient Grids, taught by Associate Professor of Mechanical Engineering Konstantin Turitsyn; 1.079 Rock-on-a-Chip: Microfluidic Technology for Visualization of Flow in Porous Media, taught by ARCO Associate Professor in Energy Studies Ruben Juanes; and 6.061/6.690 Introduction to Electric Power Systems, taught by Professor of Electrical Engineering and Computer Science James Kirtley.

Textbooks: Professors Robert Jaffe and Washington Taylor, both of the Department of Physics, completed their textbook *The Physics of Energy*, to be published by the start of the fall term. Professor Amy Glasmeier of the Department of Urban Studies and Planning wrote the book *The Economic Geography of Energy*, available both in print and online.

Undergraduate energy research: MITEI supported 20 students through the initiative's energy UROP during summer 2017; MITEI has now sponsored a total of 420 UROP projects, including Tata Center and Center for Energy and Environmental Policy Research projects. This cohort's projects ranged in focus from thermal energy storage to sulfur-reducing bacteria. Over the course of the summer, the education team conducted topical workshops and team-building activities designed to enhance skills and community among energy UROP students. Students were supported by MITEI founding members ExxonMobil and Shell, MITEI sustaining member Chevron, and individual MITEI donors.

Graduate fellows: MITEI named 25 graduate students to the Society of Energy Fellows in fall 2016. The hundreds of fellows named since 2008 have come from more than 20 departments and all five schools, and all are sponsored by MITEI members.

Freshman Pre-Orientation Program: Just prior to the start of the fall 2016 semester, 25 incoming MIT freshmen learned about their new undergraduate home—both on and off campus—in a pre-orientation program with a special focus on energy. The MITEI-led program, called Discover Energy, was designed as an interactive introduction to topics ranging from wind energy to nuclear power and climate policy, with group bonding activities throughout the week.

Undergraduate Energy Commons: In early October 2016, after more than a year of planning and construction, MITEI's Undergraduate Energy Commons, located under MIT's iconic dome in Room 10-063, opened to students, faculty, and staff. The Undergraduate Energy Commons is a mixed configuration of educational and activity space for students to gather, hold events, and collaborate on projects. Since the fall, numerous events from UROP open houses to the career insights speaker series have been held in the Energy Commons. The development of this space was made possible by a grant from the S.D. Bechtel, Jr. Foundation.

Career insights speaker series: Energy industry professionals including Sara Matasci of EnergySage, Mike Stanley of TransitX, and Michele Ostraat of Aramco Services visited MITEI to meet with current energy studies minor undergraduates and share their career journeys and advice for students considering work in the energy sector.

Solar Spring Break: This past spring, nine undergraduates participated in MITEI's new Solar Spring Break program in partnership with GRID Alternatives. Participants spent the week in Los Angeles, CA, where they installed solar panels on the home of a low-income family. Students had the opportunity to meet the homeowner and hear firsthand about the impact of their work, tour the Los Angeles Cleantech Incubator, and attend various other networking and educational events.

EdX courses: Together with the Office of Digital Learning, MITEI is making progress in creating low-carbon energy edX courses that can be accessed by learners everywhere. The courses will be directly related to the research performed in MITEI's Low-Carbon Energy Centers.

New Energy Education Task Force faculty members: Five new and returning faculty members were appointed to MITEI's Energy Education Task Force during AY2017.

Outreach

MITEI's fact-based analyses of current energy topics inform public policy, foster dialogue within the academic research community, and provide 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 are listed below.

MIT Plan for Action on Climate Change: MITEI continued to communicate its participation in MIT's five-year climate action plan through internal and external efforts related to the Low-Carbon Energy Centers, through staff members' involvement in advisory committees for the implementation of the plan, and through the formation of a working group for climate, energy, and environment communications to enhance coordination among departments, labs, and centers.

Guest speakers: Leading policymakers, academics, and industry executives spoke at MITEI-hosted events, including Lourdes Melgar SM '88, PhD '92, former Mexican deputy secretary of energy for hydrocarbons; John Deutch, Institute Professor Emeritus; and Roberto Casula, Eni S.p.A. chief development, operations, and technology officer.

Support for campus energy events: MITEI sponsored and provided staff support for campus energy events including the student-led MIT Energy Conference; MIT Energy Night; a Dongfang Electric Corporation presentation on sustainable energy, co-sponsored with the MIT Industrial Liaison Program; the MIT Energy Hackathon; a panel discussion and networking event on energy financing, co-hosted by Siemens; and various career-focused events for students.

Utility of the Future: In December 2016, MITEI released its Utility of the Future report during launch events at the National Press Club in Washington, DC, and the Florence School of Regulation in Brussels, Belgium. Industry leaders, policymakers, and fellow researchers were on hand to learn about the study and hear presentations from a panel of MITEI researchers. The event garnered extensive media coverage and engagement on social media.

2016 annual research conference: The 2016 research conference convened leaders in academia, industry, and policy around the theme “The Global Energy Challenge: Accelerating the Transition.” The first day of the conference featured a keynote address by then-US Special Envoy for Climate Change Jonathan Pershing on the implications of COP 22, as well as discussions of financing the energy transition and transforming climate goals into policies and action. The second day focused on MITEI’s Low-Carbon Energy Centers and their work addressing global energy challenges as part of the Plan for Action on Climate Change.

2017 Associate Member Symposium: The 2017 Associate Member Symposium, Consumer Engagement and the New Utility, brought together experts to explore the technical, commercial, and regulatory dynamics that are shaping consumers’ engagement with their energy service providers. It featured an impressive array of panelists from across the power sector as well as academia.

UN Climate Change Conference in Marrakech: The MITEI communications team covered MIT’s participation in COP 22 by developing news articles and sharing highlights of MIT involvement on social media.

IHS CERAWEEK: For the past four years, MIT has had a strong presence at IHS Energy’s CERAWEEK, one of the largest energy conferences in the United States. MIT speakers this year included Maria Zuber, vice president for research and E.A. Griswold Professor of Geophysics; MITEI director Robert Armstrong; and MITEI deputy director Robert Stoner. MITEI associate director Louis Carranza and the MIT Club of South Texas facilitated the free participation of many alumni at the conference.

Organization

Leadership Team

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. Team members are as follows:

Robert C. Armstrong, director

Robert Stoner, deputy director for technology and science

Martha Broad, executive director

Louis Carranza, associate director

Francis O'Sullivan, director, research and analysis

Antje Danielson, director, education

Emily Dahl, director, communications

Energy Council

The Energy Council helps shape MITEI's research, education, and outreach directions. 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), and Christopher Knittel (MIT Sloan).

External Advisory Board

The External Advisory Board, composed of industry, academic, nonprofit, and public sector leaders and chaired by former US 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

MITEI's Energy Education Task Force (EETF) guides the development of energy education at MIT. Bradford 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 in 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 task force by implementing energy education programs.

MITEI Members

MIT Energy Initiative member programs contribute to a critical link in the energy innovation chain, connecting MIT's world-class research teams with innovators in industry and government to respond to specific energy challenges and move solutions into the energy marketplace. Members provide industry perspectives on current technology challenges as well as research opportunities and critical funding for the next generation of energy technologists.

MITEI aggregates MIT's research capabilities, innovation, expertise, and experience in successful industry collaborations to help 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 that multiplies benefits to the initiative's member participants. The members benefit from opportunities to pool resources that increase the overall understanding of research and analysis for their organization.

Member Highlights

In the past year, MITEI welcomed new member companies to support various research efforts and also signed renewal agreements with existing members that expanded their commitments to low-carbon energy research.

- Founding member Eni renewed its nine-year collaboration with MITEI for another four years. Eni's renewal agreement includes research support for the Low-Carbon Energy Centers in the areas of solar energy; energy storage; and carbon capture, utilization, and storage.
- Iberdrola joined as a sustaining member, with an agreement including funding for a professorship in power systems engineering and membership in the Center for Electric Power Systems Research.
- GE became a sustaining member, joining four of the Low-Carbon Energy Centers: Solar Energy Research, Energy Storage Research, Electric Power Systems Research, and Carbon Capture, Utilization, and Storage.
- Cenovus and ENN became MITEI associate members. Each is joining a Low-Carbon Energy Center as part of its membership: Cenovus has joined CCUS, and ENN has joined the Center for Energy Storage Research.

MITEI announced the Mobility of the Future study in December 2016. This multi-year, multidisciplinary study examining the future of transportation has so far signed on the following member companies as sponsors: Alfa, Aramco Services, Bosch, BP, Chevron, ExxonMobil, Ferrovial, General Motors, SAIC-GM, Shell, Statoil, and the Toyota Mobility Foundation.

Additional updates on MITEI members that have joined the centers are provided in the section on Low-Carbon Energy Centers. A complete list of members is available on the [MITEI website](#).

Affiliated Groups

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 and jointly sponsored by MITEI, the Department of Economics, and the 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 contributions to larger, interdisciplinary studies. Also, the center conducts two annual research workshops in Cambridge, MA, and a European energy policy conference organized jointly with the Energy Policy Research Group at the University of Cambridge in the UK.

The E2e project is a collaboration initiated by Professor 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 today's most perplexing energy questions and communicating 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 Ronald G. Prinn (Earth, Atmospheric and Planetary Sciences) 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 future food, energy, water, climate, air pollution, and other interwoven 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 framework
- Independent assessments of potential responses to global risks through mitigation and adaptation measures
- Outreach efforts to analysis groups, policy-making communities, and the public
- 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 and the MIT Center for Energy and Environmental Policy Research.

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 or UMI (Unite Mixte Internationale) 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 CNRS as the lead unit of a "Laboratoire d'Excellence" consisting of multiple institutions engaged in materials science.

Office of Sustainability

The mission of the MIT Office of Sustainability (MITOS) is to transform the Institute 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 through the Office of the Executive Vice President and Treasurer, MITOS works to integrate sustainability across the 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 globe.

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.

Robert Armstrong
Director