

## MIT Energy Initiative

The [MIT Energy Initiative](#) (MITEI) is an Institute-wide initiative that links science, innovation, and policy to transform the world's energy system in order to meet the challenges of the future. As MIT's energy hub, researchers from across the Institute work with government and industry to identify tomorrow's energy challenges, develop cutting-edge solutions, and implement change by bringing new approaches to policy makers and new technologies to the marketplace. Through research, education, and outreach, MITEI's interdisciplinary approach covers all areas of the energy spectrum—from supply and demand to security and environmental impact.

In May 2013, deputy director Robert C. Armstrong was named the director, as outgoing director Ernest Moniz left the Institute to head the US Department of Energy.

Armstrong had served as the deputy director of MITEI since its founding six years ago. He was cochair (with Moniz) of the Energy Research Council, which laid the groundwork for MITEI and set its guiding principles. Armstrong has since played a leading role in the initiative's development. During his service as deputy director, MITEI supported almost 800 research projects at the Institute; it continues to engage a quarter of the MIT faculty in its projects and programs.

More than two-thirds of the projects supported through MITEI's coalition of industry, foundation, government, and private partners have been in no- or low-carbon research, including renewable energy, energy efficiency, carbon management, and enabling tools such as biotechnology, nanotechnology, and advanced modeling. The largest single area of funded research is in solar energy, with more than 100 research projects.

Projects supported through MITEI have fostered the development of such innovative technologies as low-cost solar cells that can be printed directly onto paper or other flexible, inexpensive materials; utility-scale liquid batteries that could enable grid integration of intermittent energy sources; transparent solar cells that could be built into display screens or windows; and bioengineered batteries.

More than 100 MITEI seed fund projects have served to attract many MIT faculty to energy-related research and to launch new research directions. Several MITEI-supported projects have led to the formation of start-up companies, reflecting the Institute's long-standing focus on commercializing technology solutions. Others have led to major government funding and to sponsored research programs with MITEI members.

The initiative has awarded 252 graduate fellowships in energy and supported 104 undergraduate research opportunities. The energy minor, established under the guidance of Armstrong and Moniz in 2009, is already one of the Institute's most popular minors. This experiment in interdisciplinary undergraduate education represents the first official academic program that brings together all five schools across MIT.

## Organization

MITEI seeks support from partners in industry as well as from private donors and some public institutions to support a broad portfolio of energy research. Private support of energy research is a key link in the research value chain, as is federal funding of energy research. Cooperation among academia, industry, and government is essential for meeting global energy needs, addressing climate change resulting from fossil fuel combustion, and transforming global energy systems. At the national level, Institute leadership has been actively engaged in raising awareness of the importance of federal investment in energy research and development in the United States.

Along with director Bob Armstrong, MITEI's leadership team includes the deputy director for research and technology, Robert Stoner. A deputy director for policy will be named in the upcoming fiscal year. The directors are members of the Energy Council, which helps shape MITEI research, education, and policy directions. The council also includes professors Angela M. Belcher (Materials Science and Engineering and Biological Engineering), Vladimir Bulović (Electrical Engineering and Computer Science), John M. Deutch (Chemistry), Leon R. Glicksman (Architecture and Mechanical Engineering), and Richard Schmalensee (Sloan School of Management).

The initiative's External Advisory Board provides strategic direction for MITEI and MIT's energy programs. George Shultz chairs the board, which is composed of industry, academic, nonprofit, and public-sector leaders. It met for the sixth time in October 2012.

The MITEI education and campus energy programs are each overseen by a task force comprising faculty members and students from all five of MIT's schools who develop new directions and support activities in those two realms of opportunity at MIT.

## MITEI Members: Partnerships in Research and Education

Consistent with MIT's history of engaging with industry, MITEI reflects the understanding that robust research partnerships between academia and industry are highly effective vehicles for transforming the global energy marketplace.

Achieving these outcomes through specific research programs involves multiple academic disciplines and personnel, supported by an infrastructure that maximizes opportunities for MITEI's industry partners. MITEI aggregates MIT's research capability, innovation, expertise, and experience in successful industry collaborations to help meet its research partners' key strategic objectives. A multitiered membership structure enables private-sector partners to sponsor multidisciplinary, multiple-faculty "flagship" research programs; contribute to a range of energy-focused MIT labs, programs, and centers; fund critical energy fellowships; support innovative energy concepts from proposals solicited across the campus; and participate in MITEI-organized seminars, lectures, and colloquia.

In the past year, Eni renewed its founding membership; Saudi Aramco moved from a sustaining member to a founding member; Bosch, Chevron, and Total renewed their sustaining memberships; four new associate members, Booz Allen Hamilton, Duke

Energy, Edison International, and NREL, joined MITEI; Entergy, Hess, Cummins, and EDF renewed their associate memberships; and six affiliate members joined MITEI.

### MITEI Members, as of June 2013

#### FOUNDING MEMBERS

BP  
Eni S.p.A.  
Saudi Aramco  
Shell

#### SUSTAINING MEMBERS

Robert Bosch  
Chevron U.S.A. Inc.  
Ferrovial  
Lockheed Martin  
Schlumberger  
Siemens  
Total  
United Technologies Corporation  
Weatherford International Ltd.

#### ASSOCIATE MEMBERS

Booz Allen Hamilton  
Cummins  
Duke Energy  
EDF  
Edison International  
Enel  
Entergy  
Hess  
ICF International

#### AFFILIATE MEMBERS

8 Rivers Capital  
Albachiara Rinnovabili S.r.l.  
Angeleno Group  
Asociación Nacional de Empresas  
Generadoras  
Aspen Technology, Inc.  
Larry Birenbaum '69  
Bloomberg New Energy Finance  
John M. Bradley '47, SM '49  
Constellation Energy

Lisa DoHimawan '88  
Jerome I. Elkind '51, ScD '56  
EnerNOC, Inc.  
Ernst & Young LLP  
Dennis Fromholzer  
Fundació Barcelona Tecnològica (b\_TEC)  
Gas Technology Institute  
Natalie M. Givans '84  
C. Gail Greenwald  
Thomas Guertin PhD '60  
Harris Interactive  
Hogan Lovells US LLP  
IHS Cambridge Energy Research Associates  
George Lee and Elaine Chong '03  
Paul Mashikian '95, '97  
MassCEC  
New York State Energy Research and  
Development Authority  
Nexant, Inc.  
NGP Energy Technology Partners, LP  
Open Access Technology International, Inc.  
Osaka Gas Co., Ltd.  
Patriot Renewables  
Petra Energia S.A.  
Praxair, Inc.  
Pythagoras Investment Management, LLC  
Joseph M. Rault '48, president, Rault Resources  
Group  
Redpoint Ventures  
Philip Rettger '80  
Rockport Capital Partners  
S. Kinnie Smith, Jr.  
Doug Spreng '65  
Step toe and Johnson, LLP  
George R. Thompson, Jr. '53  
The Tremont Group, LLC  
Tomas Truzzi  
Westport Innovations, Inc.  
Xandex, Inc.

## Research

MITEI is designed to mobilize the Institute's research and educational capabilities to help meet the world's most pressing energy challenges. MITEI's interdisciplinary research program and related education and campus-wide activities focus on:

- Innovative technologies and underlying policy analysis that will improve how we produce, distribute, and consume conventional energy
- Transformational technologies to develop alternative energy sources that can supplement and displace fossil fuels, including the economic, management, social science, and policy dimensions needed for this transformation
- Global systems to meet energy and environmental challenges through a multidisciplinary systems approach that integrates policy, design, and technology development
- Tools to enable innovation, transformation, and simulation of global energy systems through strategic basic research

Each of these foci includes several subgroups of disciplinary and interdisciplinary interest.

## Seed Fund Program

In the past year, MITEI selected the eighth group of projects submitted by MIT faculty and senior researchers to receive Seed Fund Program research grants. In this year's round of funding, MITEI awarded more than \$2 million to 14 new projects, each lasting between one and two years. The funded projects span nine MIT departments, laboratories, centers, and institutes and four of the schools. Funding for these grants comes chiefly from MITEI's founding and sustaining members, supplemented by funds from John M. Bradley '47, SM '49 (Bradley MITEI Innovation Seed Fund), an anonymous donor, and MIT alumni. The program supports innovative early-stage research projects addressing energy and related environmental issues. Past seed-funded projects have led to major research funding from a variety of sources and to spinoff companies.

## International Initiatives

MITEI has cultivated a spectrum of ongoing international relationships, including major programs with Tsinghua University and Cambridge University, Shanghai Jiao Tong University, the Norwegian University of Science and Technology, and the government of Portugal. In addition to several initiatives with partners in China, ongoing and new programs are under way in India, Russia, Spain, France, the United Kingdom, Chile, and Brazil. A special area of concern is the world's developing countries.

## Developing Countries

Led by China, developing countries collectively emit the majority of greenhouse gases, and their influence on future climate change and role in energy markets will increase throughout this century as they become richer and their consumption of energy and other resources grows. Recognizing this, MITEI has made a strategic effort in recent years to foster new partnerships with public and private stakeholders in China, India,

Latin America, and Africa, where ongoing rapid economic growth is driving innovation and investment and creating unprecedented opportunities for research and education. Our work is now bearing fruit across a range of endeavors.

## **India**

### *Solar Energy Research Institute for India and the United States*

Our bid to form one of three research consortia under the \$125 million US-India Joint Clean Energy Research and Development Center was selected in mid-2012 and became operational this year. The consortium's research is focused on sustainable photovoltaics, multiscale concentrated solar power, and solar energy integration. The National Renewable Energy Laboratory leads the US team, which also includes eight other universities and two national labs, with matching funding provided by five private companies. A parallel Indian team led by the Indian Institute of Science, Bangalore, includes the Indian Institute of Technology, Bombay; the Indian Institute of Technology, Madras; and eight other Indian research institutions and companies.

MIT research projects are addressing novel earth-abundant solar cell materials (professor Tonio Buonassisi) and community-scale concentrated solar power (professor Harold Hemond). Total funding for these projects is \$1.1 million over five years.

### *Tata Center for Technology and Design*

The Tata Center for Technology and Design was launched in the summer of 2012 with a generous gift from the Tata Trusts, chaired by External Advisory Board member Ratan Tata. The mission of the center is to create a graduate education program that teaches students how to apply deep technical knowledge to the challenges of the developing world, guided by direct experience in India. The program is open to master's and PhD students from all schools and departments. These students are required to satisfy their departmental course and thesis requirements and, in consultation with their departmental supervisors, develop thesis projects that respond to large-scale opportunities to use technology effectively to improve the lives of those in the lower strata of Indian society. The center is codirected by Charles Fine and Dr. Stoner.

The center provides full tuition and stipend support for all participating students (known as Tata Fellows) for up to two years, as well as travel funds that enable students to spend several months in India, mainly during Independent Activities Period (IAP) and summer months. In India, they work closely in representative rural and urban Indian communities with commercial partners, nongovernmental organizations (NGOs), and government officials whose perspectives and insights ultimately help to shape their thesis projects. In the course of two years, students are expected to produce product or system designs that provide greater access to modern health care, energy and water, housing, and agriculture by overcoming the challenges presented by the context of developing India, including widespread poverty, overcrowding, inadequate public infrastructure, shortages of energy and water, and severe environmental degradation.

The first cohort of 17 students was installed in AY2013, and in AY2014 the planned steady state of approximately 40 will be reached. The majority of the AY2014 projects were

selected through a campus-wide competitive proposal process open to all MIT faculty, who were then asked to nominate highly qualified incoming students (subject to final approval by the center directors). Faculty advisors will also receive funds for travel, as well as equipment and discretionary funds in proportion to the number of students they advise. In most cases, projects will be only loosely defined at first and then refined during the first year by students and their advisors on the basis of their experience in the field.

The center also has funded a substantial renovation of the widely used Hobby Shop and will provide additional prototyping equipment there, as well as at the Center for Bits and Atoms, for general use by fellows and the MIT community at large.

The center's directors are now working closely with Tata and his team to establish a sister center in India. This "India Center" will pursue a mission that closely parallels that of the MIT center, and it will involve a substantially similar curriculum. Designing and developing this curriculum will be an important and significant undertaking at MIT over the next several years. So far, the center has funded the development of three new MIT graduate classes that bring students into contact with developing world design challenges in mechanical engineering, architecture, and health care technology; in addition, a "proseminar" course will use lectures and case studies to provide a formal basis for understanding the socioeconomic context of India and other parts of the developing world. New classes will be introduced at a similar rate each year in various fields as needs are identified.

The first cohort of students will enter the India Center by no later than 2015–2016. The new center will serve three main purposes:

- Engender a sense of common purpose and method by bringing MIT faculty and students into frequent contact with their local peers and collaborators in India
- Become a unique India-focused graduate institution for Indian engineers and entrepreneurs
- Serve as the center of a nationwide and ultimately global network wherein educators will come to learn our new method and carry it back with them to their home institutions

## **China**

### *Low Carbon Energy University Alliance*

The Low Carbon Energy University Alliance (LCEUA) was formed in 2009, with seed funding provided by the Chinese government, to provide a platform for collaborative research on low carbon energy technology and policy with a particular emphasis on China. Its three members are MIT, Cambridge University, and Tsinghua University (which also administers the alliance's funds). In its first two years, the alliance presented eight seed research awards totaling \$4.8 million. No new seed awards have been offered since 2011, as the government of China unexpectedly withdrew its financial support for further research.

### *China Energy and Climate Project*

In parallel with LCEUA's project-oriented technology and policy program, researchers at Tsinghua University and MIT's Joint Program on the Science and Policy of Global Change launched a five-year program (sponsored jointly by MITEI founding members Eni and Shell and associate member ICF International) to analyze China's national economy and its energy system in the context of climate change. The program seeks to develop highly granular simulation models for China that will eventually be comparable to those already developed by the Joint Program for the United States and will serve as a basis for informed negotiations concerning greenhouse gas emissions and climate change mitigation.

### *MIT-China Low Carbon Energy Leaders Program*

At the recommendation of the MIT Greater China Strategy Committee, MITEI launched a novel executive education program on energy technology and policy in April 2011 called the MIT-China Low Carbon Energy Leaders Program. With the aim of equipping participants to develop effective strategies to balance the competing demands of economic growth and environmental stewardship through policy and practice, each seven-day session presents Western perspectives on energy technology and the environment as represented by the MIT faculty.

MITEI and our collaborators at Shanghai Jiao Tong University delivered sessions four through six at MIT in 2012 and will conclude this partnership with two final sessions in the coming year. In all, more than 150 Chinese executives and senior provincial and national government officials will have participated over the initiative's three years. The program, which earns a modest profit for MITEI, was recently named the top executive education program for Chinese officials offered outside China last year.

### *Developed Country Partnerships*

#### *Skolkovo Institute of Science and Technology*

Following the signing of a collaboration agreement among MIT, the Skolkovo Foundation, and the Skolkovo Institute of Science and Technology (Skoltech) in October 2011, MITEI has been engaged in Institution-wide efforts to build capacity in education, research, and innovation programs at Skoltech. Energy science and technology is one of five strategic areas of focus at the new graduate research university. MIT's contributions to the Skoltech energy programs are being led and coordinated through MITEI by Dr. Raanan Miller MBA '08, with the program curricular elements supported by Dr. Amanda Graham. MITEI director Armstrong has supported faculty and director recruitment and curriculum design.

As part of the collaboration, MITEI has analyzed strategic energy research needs together with Skoltech and Russian industry and defined research opportunities that align Russian industry, Skoltech, and MIT priorities. It has conceived of and supported development of an industry engagement model for Skoltech that more effectively links industry with the university and faculty. MITEI has played a leading role in helping to foster worldwide submission of strong, relevant energy proposals for centers for research, education, and innovation (CREI) at Skoltech. It has established and led search

committees for energy-related CREI directors, identifying strong candidates willing to relocate to Russia. MITEI has proposed and led an effort, in collaboration with the MIT-Skoltech Initiative, to create an energy industry immersion program modeled after the Chemical Engineering Practice School. It is also developing other core energy-related graduate programs and curricula of relevance for both Skoltech and MIT in areas such as power systems and oil and gas exploration, recovery, and processing.

#### *International Joint Unit: French National Center for Scientific Research and MIT*

The International Joint Unit (UMI) program involving MIT and the French National Center for Scientific Research (CNRS) has grown this year under the direction of director Roland Pellenq and codirector Franz Ulm. Dr. Benoit Coasne (CNRS/University of Montpellier), a visiting professor in Department of Civil and Environmental Engineering (at the principal research scientist level), has joined UMI and taken the lead on the simulation thrust of the Xshale program on shale gas (which is part of MITEI).

When additional visiting professors arrive by the end of summer 2013, UMI staff will be composed of five full-tenured CNRS personnel as originally planned and announced for the UMI project. UMI funds are also used to support postdoctoral associates, including Dr. Mathieu Bauchy (Concrete Sustainability Hub) and Dr. Colin Bousige (Xshale project).

In addition, project funds are used to increase UMI's research effort and capabilities. For instance, Dr. Coasne was awarded a grant from the Needs Program (a European program on nuclear waste) that is funding a UMI visiting scholar and Dr. Remko Hartkamp. Hartkamp is working on nuclear applications of cement. The University of Montpellier in France funds UMI postdoc Guido Ori. In addition, UMI is hosting a visiting PhD student, François Villemot from the University of Montpellier, who is working on transport of confined fluids in hierarchical porous materials. In June 2013, UMI was awarded a postdoctoral grant from France's National Research Agency on hydrogen storage in nanoporous materials.

On the educational front, UMI is fully associated with the Marseille Winter School on Multiscale Porous Materials. The first weeklong program, launched in January 2013, gathered lecturers from MIT, ETH Zurich, and Paris and Marseille universities as well as students from Marseille, Imperial College London, ETH Zurich, and MIT and a few attendees from industry.

UMI has substantially increased its research portfolio and funding. CNRS has fully complied with its duties and engagements as described in the signed agreement between the parties. In conclusion, this past year was used to bring UMI to full speed.

### **Education**

Catalyzing students' knowledge and enthusiasm to solve technologically, socially, and politically challenging problems is a central component of the MITEI program. Education is closely integrated with MIT's energy research and with campus energy management activities.



MITEI's Energy Education Task Force (EETF) guides the development of energy education at MIT. Professors Amy Glasmeier (Urban Studies and Planning) and Jeffrey Grossman (Materials Science and Engineering) cochair the task force. 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. Professional staff members in MITEI's Education Office support MITEI and EETF in implementing energy education programs.

### **Energy Studies Minor**

The energy studies minor's multidisciplinary curriculum integrates energy science, social science, and technology/engineering and is open to students from all majors. With the graduation of its fourth cohort in June 2013, the energy minor now includes graduates from all five schools and 14 departments. It was the sixth-largest undergraduate minor completed by students in AY2013.

The Energy Minor Oversight Committee (EMOC), a subset of the standing Energy Education Task Force with members from all five schools, is responsible for the intellectual content of the minor. EMOC met regularly throughout AY2013. In 2012, the Inter-School Educational Council's three-year experiment relating to the governance of the energy minor expired, and oversight responsibility for the minor was transferred to MITEI director Armstrong. EMOC and MITEI will report on the minor to the Committee on the Undergraduate Program and the Committee on Curricula every five years.

### **Curriculum Development and Dissemination**

EETF supported major adaptations for two classes in AY2013. Subject 3.012 Fundamentals of Materials Science and Engineering was transformed from lecture-based to demonstration-driven delivery, and a major new laboratory module on the design and testing of solar cells was developed for incorporation into 3.155J/6.152J Micro/Nanoscale Processing Technology. More than 25 subjects eligible for energy minor credits have been published on OpenCourseWare (OCW). In spring 2013, the total number of visits to all energy classes published on OCW reached 1 million.

### **Energy Undergraduate Research Opportunities Program**

Participation in MITEI's summer Undergraduate Research Opportunities Program (UROP) grew to 38 students from 12 departments working on energy projects during summer 2013. Projects range from investigating low-cost electrolytes for liquid metal batteries to developing low-power environmental sensing technologies for Amazon River communities and working on controlled stamping of quantum dot films. MITEI summer 2013 UROP students are supported by MITEI founding members BP and Shell; sustaining members Chevron, Lockheed Martin, Schlumberger, and United Technologies Corporation; six MITEI affiliate members; and one alumni donor.

### **Graduate Energy Fellows**

The Society of Energy Fellows at MIT has grown to more than 250 members with the designation of the 2012–2013 cohort of graduate students representing 17 departments and all five schools. The fellowships are supported by a group of MITEI's founding,

sustaining, and associate members. The Society of Energy Fellows at MIT plays a key role in MITEI's intellectual and educational mission by cultivating a community of graduate students with a wide range of disciplinary perspectives and talents focused on a common set of energy challenges. Society-sponsored activities in 2012–2013 included an afternoon symposium and poster reception on the eve of MITEI's Fall Research Conference (October), meetings and discussions hosted by sponsors for their groups of fellows, and a range of informal gatherings.

### **Energy Education Without Borders**

The Energy Education Without Borders program supports graduate students performing field studies or presenting research results at conferences around the world. Short-term travel grants were awarded to 20 MIT graduate students from across the Institute in 2012–2013.

### **Internships and Career Development**

MITEI continues to expand efforts in the area of internships and career development, with a particular emphasis on connecting students with opportunities at MITEI member companies. MITEI hosted lunch seminars and informal events for students with industry representatives to discuss specific opportunities as well as career pathways more broadly. More than 300 students from across the Institute are engaged in an energy internship opportunities email list. MITEI works closely with the MIT International Science and Technology Initiatives (MISTI) program, Global Education and Career Development, and other internship-related offices and programs on campus to encourage and support energy-related career opportunities.

### **Campus Energy Management**

The Campus Energy Task Force continues to advance MITEI's vision of engaging our MIT community in campus energy activities. The task force has supported and coordinated a broad community of departments and people, including department heads, research scientists, faculty, department staff, custodians, administrative assistants, and undergraduate and graduate students, to help MIT "walk the talk" on energy and sustainability. The campus energy program has provided a coordinating structure and opportunity to affect campus energy use, to foster an awareness of energy issues across campus, and to allow many more people to engage with, learn from, and enrich the MIT Energy Initiative in different capacities. Professor Glicksman and executive vice president and treasurer Israel Ruiz cochair the task force. Members include faculty from all five schools and administrative leaders from all major units, as well as graduate and undergraduate student representatives. The task force meets monthly.

### **Accomplishments**

FY2013 highlights include successful completion of the third and final year of the pilot phase for MIT Efficiency Forward—the industry-leading energy conservation and efficiency program—achieving the program's goal to save 34 million kWh annually, representing expected savings of \$50 million over the lifetime of the program's projects.

In what is considered to be the first agreement of its kind, MIT, Harvard University, and the city of Cambridge developed a compact to work collaboratively to address issues related to climate change on a local basis. The “Community Compact for a Sustainable Future” lays out a framework for the signatories to work in a more coordinated and robust fashion to tackle local sustainability challenges.

The pilot building-occupant engagement program focused on developing “green teams” is being implemented in the Koch Institute for Integrative Cancer Research. Efforts this year included waste and recycling assessments and action plan development, administration of a Koch Institute staff survey to establish baseline data on awareness of sustainability issues, outreach and education events, and a focus on developing a food waste–composting program.

MIT’s campus transportation program continues its efforts to reduce the rate of people driving to work alone to 20%, thus increasing alternative modes of transportation.

MIT successfully installed two Boston Hubway bicycle stations, bringing the Boston-based commercial bike rental program across the river to Cambridge. MIT participation in the bike-share program has exceeded expectations.

Task force members collaborated closely with instructors in several departments to examine key issues in campus sustainability, including storm water management, community-based energy efficiency strategies, and building technologies for energy efficiency in their courses.

MIT has made strong progress in the US Department of Energy’s Global Superior Energy Performance (GSEP) Partnership, piloting the program’s new building energy management certification program, and is also nearing completion of MIT’s ISO 50001 energy management documentation. MIT’s participation in DOE’s Commercial Building Partnership led to national laboratory technical assistance and advanced energy efficiency strategies in Buildings 32 and W91.

In June, the Office of the Executive Vice President and Treasurer created MIT’s first Office of Sustainability, reporting directly to Israel Ruiz. The office will spearhead an expansion and coordination of campus energy and sustainability programs across campus and in the community.

## **Energy Conservation, Efficiency, and Sustainable Design**

### ***Energy Conservation and Efficiency***

From FY2007 through FY2013, MIT successfully accumulated nearly \$5 million in annual energy savings. Major electrical and thermal savings were achieved through investments in lighting, central utility plant upgrades, new construction systems, demand ventilation, variable-speed drives, air change rate reductions, chiller upgrades, and residence hall refrigerator replacements.

MIT exceeded Efficiency Forward's first-year energy savings goal by 30 percent. In the second year of the program (concluding December 31, 2011), MIT surpassed its cumulative two-year goal of reducing annual electricity use by 22 million kWh. In calendar year 2012, MIT reduced its electricity use by more than 12 million kWh, contributing to a total annual savings of 34 million kWh (approximately 15% of MIT's benchmark annual electricity use).

Designed to build on MIT's strengths to create a model program that would meet state greenhouse gas reduction goals, Efficiency Forward is the single largest energy-efficiency project that gas and electric utility NSTAR has ever developed with a customer. Together, NSTAR and MIT invested more than \$13 million in energy conservation over the program's three-year pilot phase to meet their targeted goal of reducing the Institute's energy consumption by 34 million kWh per year. Approximately 40% of the program's overall goal was met through new building features. Another 40% came from upgraded lighting and associated controls, while 20% of the goal was met by improving the efficiency of mechanical systems and systems for heating, ventilation, and air conditioning.

In May 2013, MIT and NSTAR signed a second agreement to renew the Efficiency Forward program through 2015 and are designing a new portfolio of measures that have an ambitious goal of saving an additional 21 million kWh annually. For this second phase, Efficiency Forward will now also include thermal savings from the reduction of natural gas use on campus, with a goal of saving 150,000 therms of natural gas annually over the next three years.

Since Efficiency Forward launched in 2010, MIT has saved nearly \$5 million in annual operating costs as a result of the energy efficiency and conservation strategies utilized during the program and is expected to capture \$50 million in savings over the lifetime of the projects. MIT is expected to save an additional \$2.3 million annually from the new three-year program. Efficiency Forward includes a commitment to reinvesting a portion of these savings into future projects.

As of the end of FY2013, energy efficiency investments had touched more than 90% of the buildings on the MIT campus.

The Massachusetts Green High Performance Computing Center (MGHPCC) was completed in November 2012. MGHPCC is a data center dedicated to supporting the growing research computing needs of five of the most research-intensive universities in Massachusetts: Boston University, Harvard University, MIT, Northeastern University, and the University of Massachusetts. The center demonstrates many energy efficiency and sustainability strategies, including advanced cooling techniques, energy-efficient power distribution and control, use of renewable energy, and brown site redevelopment.

### ***A Network of Change Agents***

This year, the pilot building-level occupant engagement program was continued to test a new approach to fostering sustainable practices by individuals within buildings. The program, which is being piloted in the Koch Institute, centers on the development

of building-level green teams that conduct baseline assessments of energy use, waste management, and procurement practices; identify key strategies to improve sustainable practices; and support individual action through promoting awareness and providing incentives. The Sustainability Program of the Environment, Health, and Safety Office (EHS) is supporting this pilot program.

The Green Ambassadors Program—established to create and empower a network of individuals interested in taking action in their own lab, office, or dormitory to promote more sustainable practices at MIT—has grown to include more than 400 staff, faculty, and student volunteers who model and promote the Institute’s energy and environmental stewardship objectives.

### **Student Learning, Research, and Engagement**

MIT’s campus operations are being used as a living laboratory to foster students’ emerging technical and leadership skills to help define and solve our own energy challenges.

As noted, Campus Energy Task Force members collaborated closely with instructors in several departments to examine key issues in campus sustainability including storm water management, community-based energy efficiency strategies, and building technologies for energy efficiency. For example, professor Jim Wescoat from the Department of Architecture led student teams in researching and developing innovative green infrastructure improvements in future east campus developments in collaboration with the MIT Investment Management Company, the Department of Facilities, and EHS. In addition, professor Harvey Michaels from the Department of Urban Studies and Planning led student teams, in collaboration with the city of Cambridge, in developing innovative pilot programs to increase energy efficiency in multifamily rental housing in Cambridge.

Through the MITEI Student Campus Energy Project Fund, MIT has supported more than 45 student projects on campus that engage our students and advance our campus energy objectives while simultaneously providing rich learning opportunities. For example, in the spring, the task force provided support to an undergraduate team to bring back the Dorm Electricity Competition.

### **Outreach**

MITEI’s outreach program has two distinct components. First, it brings outside experts to campus to enrich and broaden the MIT community’s understanding of energy issues and challenges. Second, it maximizes the impact of MIT and MITEI research and analysis by sharing the results of these activities with a broad external audience of energy, policy, environmental, and industry leaders.

The group is responsible for producing a wide range of meetings and published materials that steadily increase in type and number each year. The list of public and private events supported by the group over the past year included more than 100 separate meetings.

The outreach program produces and/or facilitates reports and studies such as the “Future of...” series and the Associate Members Symposium series, public and invitational events, publications, digital outreach, and video presentations, media relations, and publicity in support of MITEI-sponsored events.

### **Studies and Reports**

MITEI’s outreach activities have included six major “Future of...” studies in the past seven years. These multiyear, multidisciplinary studies are designed to provide policy makers, researchers, environmentalists, and industry with technically grounded analyses to inform options for a clean energy future. MITEI is currently completing the Future of Solar Energy study, which should be completed at the end of 2013 and released in early 2014.

Another [group of publications](#) comes from the MITEI Associate Member Program series. These meetings are designed to bring together groups of energy experts and stakeholders to discuss critical and timely energy issues. After each symposium, a report is prepared and published, detailing the proceedings and providing a range of findings and recommendations. Graduate student research assistants involved in each project contribute supplemental information to the final presentations. This year a report was created that addresses prospects for bi-fuel and flex-fuel light-duty vehicles, the topic of the 2012 symposium. Also, the report from the April 2013 symposium (“Growing Concerns, Possible Solutions: The Interdependency of Natural Gas and Electricity Systems”) is in review.

### **Meetings and Events**

Attendance at publicly available MITEI-sponsored events has been enthusiastic, demonstrating a high level of demand for energy-related information throughout the MIT and local communities. Highlights from this year’s more than 100 meetings include the first annual Women in Clean Energy Symposium, the Land-Water Nexis Workshop, the third Game Changers meeting and accompanying meetings on the Hill with Senator Lamar Alexander (R-Tenn) and Speaker John Boehner (R-Ohio), an on-campus debate on energy with representatives of the 2012 presidential candidates, and an Earth Day address by Massachusetts governor Deval Patrick.

### ***Women in Clean Energy***

In support of developing national-level capacity, MIT partnered with the Department of Energy to fulfill the US commitment to the Clean Energy Ministerial’s Clean Energy Education and Empowerment initiative launched by nine governments in 2010. The MIT-DOE Women in Clean Energy program includes the naming of 30 Energy Ambassadors, an awards program, and an annual major conference. The first annual, invitation-only Women in Clean Energy Symposium, with more than 200 participants, laid the foundation for a broader, continuing effort to support and enhance educational and career opportunities for women in clean energy.

The symposium’s speakers ranged from those working on small-scale individualized energy solutions to those working at the highest levels of government or corporations.

As these leaders pointed out, with many national and international energy plans stalled, local initiatives often are leading the way. Among other things, energy efficiency has been embraced by some states and cities, forging ahead of national standards.

Six midcareer women received awards for their work in clean energy, and a Lifetime Achievement Award was presented to Millie Dresselhaus, MIT Institute Professor of electrical engineering.

### ***Land-Water Nexus Workshop***

On May 6 and 7, MITEI held the Land-Water Nexus Workshop at the Center for Strategic International Studies (CSIS) in Washington, DC. The workshop, sponsored by MITEI founding member BP, brought together nearly 200 researchers to offer their expertise and insights on creating a coherent, forward-looking research agenda on the energy-water-land nexus.

The workshop grew out of the Energy Sustainability Challenge, a multiyear, multi-university research program sponsored by BP. The program addresses the question of how natural resource constraints will change the way energy is produced. Water-related issues are recognized as one of the next big challenges in the energy industry, and tackling them in a cohesive manner has been difficult.

The workshop was designed to bring researchers together from many of the 13 universities sponsored by this BP program, along with other leading experts with knowledge and understanding of the technology, economic, policy, and systems issues surrounding the constraints, particularly land and water constraints on energy sustainability going forward. The forum allowed interactive discussions between participants with varying opinions.

After the workshop, researchers from MIT and CSIS discussed the findings at the White House Office of Science and Technology Policy. A report will be developed in the upcoming academic year.

### ***Game Changers***

On March 7, researchers from MITEI and Stanford's Hoover Institution met in Washington, DC, to explore the latest energy technologies and to advocate for stronger and sustained investment in research and development to help move these technologies from the laboratory to the marketplace. This was the third and last in a series of meetings aimed at identifying game-changing energy technologies.

These clean energy technologies can boost America's long-term economic growth and will allow us to confront our nation's growing energy needs, security concerns, and environmental challenges such as climate change. During the daylong event, the researchers examined three critical technology areas: transportation, electricity and the built environment, and infrastructure. A book highlighting MIT and Stanford game-changing research is being created and will be sent to policy makers and others in the energy field.

### **Presidential Debate**

On October 5, representatives of president Barack Obama and his Republican challenger, former governor Mitt Romney, squared off in a crisp debate about energy that revealed significant differences between the candidates.

At the event, cohosted by MITEI and the MIT Energy Club, Oren Cass, domestic policy director for Romney, emphasized that the former Massachusetts governor believes increased domestic fossil-fuel production should be the principal priority of energy policy while asserting that government should play a minor role in incentivizing energy technology deployment and dismissing the need for assertive policy-making on climate matters.

Representing President Obama, Joe Aldy, a professor at Harvard University's Kennedy School of Government who served as a special assistant to Obama for energy and environment in 2009 and 2010, made the contrasting case that an "all-of-the-above strategy" — one that includes increased production, technological innovation, and efficiency — is needed to address America's energy needs.

The 90-minute debate, in front of a crowd of several hundred in MIT's Kresge Auditorium, was moderated by Jason Pontin, editor in chief and publisher of *Technology Review*. In addition to the moderator, three journalists with energy reporting experience, three students from area universities, and an MIT Knight Science Journalism fellow offered questions.

### **Earth Day Address**

In April 2013, Massachusetts governor Deval Patrick delivered his second Earth Day address. In an Earth Day address in 2008, Patrick outlined an ambitious set of goals that he said could achieve significant reductions in greenhouse gas emissions and create businesses and jobs based on clean-energy solutions. In a follow-on talk this past April, he described a series of successes in meeting these goals.

He said that five years ago, Massachusetts took a fresh look at its energy future. He noted that with no oil, coal, or gas of its own, the state is at the end of the pipeline and is subject to the whims of a global energy market. To address this issue, Patrick pushed for three pieces of legislation: the Green Communities Act, which set ambitious goals for renewable energy; the Global Warming Solutions Act, which set a series of goals for reducing greenhouse gas emissions; and the Green Jobs Act, which focused on capturing opportunities to foster innovation and create jobs.

He said the measures are working. In fact, the American Council for an Energy-Efficient Economy has ranked Massachusetts first among the US states in energy efficiency for two consecutive years — ahead of long-time leader California.

### **Publications and Digital Media**

Energy Futures, MITEI's semiannual magazine, conveys the high points of MITEI activities to a wide audience. MITEI also produced a volume of the 2012 research,



education, and outreach spotlights featured on the MITEI website and News Office home pages. In addition, the monthly e-newsletter (delivered during the academic calendar year), inaugurated less than two years ago, now has 4,000 subscribers. It keeps the community updated on MITEI activities and progress, particularly events where public involvement is welcome.

The outreach group has initiated a social media plan, with stories being posted on Facebook and Twitter; in addition, MITEI had its second “tweet up” this past year to promote the Women in Clean Energy program. As of the end of FY2013, MITEI had more than 2,000 followers on Twitter and more than 1,700 on Facebook.

### **Affiliated Groups**

Faculty members in several MIT centers, programs, and laboratories pursuing interdisciplinary energy and environmental activities are affiliated with MITEI through the financial administration of certain projects and through research and educational activities shared through the various component programs.

### **Center for Energy and Environmental Policy Research**

The Center for Energy and Environmental Policy Research (CEEPR), which funds policy-related research in energy and environmental economics, is jointly sponsored at MIT by MITEI, the Department of Economics, and the Sloan School of Management. The center receives financial support from corporate sponsors and government agencies. CEEPR is codirected by professors Chris Knittel and Dick Schmalensee.

CEEPR research has a number of emphases, including the restructuring of electricity markets, evaluating the functioning and performance of markets created for environmental services, and evaluating the future of nuclear, coal, gas, and renewable energy sources as well as the functioning of global trade in oil and natural gas. CEEPR also supports econometric work in the evaluation of environmental regulations and programs. Finally, research includes analyses of the financing of large-scale investments as well as the price dynamics and risk in these markets.

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

The Joint Program on the Science and Policy of Global Change integrates natural and social science to produce analyses relevant to climate and energy policy debates. Codirected by Dr. John Reilly and professor Ronald Prinn, the Joint Program combines traditional strengths in science and economics to conduct the interdisciplinary work needed to evaluate the effects of climate change on the economy and on natural systems and to explore how to adapt to the potential impacts of environmental change. The 22-year-old program is recognized as a world-leading center for integrated assessment of global change.

The program has a unique analytical facility and supporting analysis capabilities for investigation of the complex connections among human activity and the global environment, as well as the associated uncertainties. The cornerstone of this effort is the MIT Integrated Global System Model framework that is applied to studies of

human-earth system interactions and climate change risk, social and environmental impacts, and analysis of potential mitigation and adaptation responses. A team of faculty, professional research staff, postdoctoral fellows, and graduate students carry out the work and communicate the research results, analysis methods, and assessment conclusions to a broad range of audiences.

Through publications, presentations, workshops, and briefings, the program's work is conveyed to policy makers in the United States and other countries, industry leaders, other analysis groups in the climate community, environmental organizations, journalists, students and educators, and the public at large. The effort is supported by seven US federal agencies and an international consortium of industrial, foreign government, and foundation sponsors in North America, Europe, Japan, and China.

## **Laboratory for Energy and the Environment**

### ***Analysis Group for Regional Energy Alternatives***

MIT Energy Initiative research in the area of integrated planning for local and regional energy infrastructures is centered in the Analysis Group for Regional Energy Alternatives (AGREA), led by Stephen Connors. Through the MIT Portugal Program and the Engineering System Division's Center for Complex Engineering Systems (a collaboration between MIT and King Abdulaziz City for Science and Technology), AGREA focuses on how to dramatically reduce energy use and emissions on the local and regional scale. Technology portfolios incorporating high-penetration renewables, smart energy uses including electric transportation, energy storage, and transformations of the built environment require a detailed understanding of local energy system operations as well as the combined dynamics of solar, wind, and other renewables and how they match the dynamics of local energy needs.

The scenario-based tradeoff-analysis approach—developed in the early 1980s by MIT Energy Laboratory researchers—is the primary tool used by AGREA. Ongoing and recent research activities include projects in the MIT Portugal Program's Sustainable Energy and Transportation Systems focus areas, most notably the Azores Green Islands Project, as well as new efforts elsewhere in Europe and the Middle East including Saudi Arabia, Cyprus, and other European island systems. AGREA's bottom-up approach helps both policy makers and private-sector innovators identify new market niches for clean energy technologies. Past projects have focused on New England, Mexico City, Northern Europe, Switzerland, the United Kingdom, Argentina, and Shandong, China.

In addition to the projects and programs listed above, Connors advises numerous graduate and undergraduate students in other projects and programs at MIT, looking at fuel consumption and emissions impacts among renewables and fossil fuels; challenges to the development of new renewable industries such as offshore wind, electrification of transportation, energy storage, and smart grid technologies; the potential impacts of the widespread deployment of distributed generation to electrification in developing countries; and real options applications to energy investments involving climate change, economic growth, and energy security. Details are available at the [AGREA website](#).

### ***Martin Family Society of Fellows for Sustainability***

Twenty advanced graduate students from 10 departments were selected for the 2013–2014 Martin Fellows cohort. More than 300 doctoral students from all five schools and more than 25 departments have been supported by the Martin Family Society of Fellows for Sustainability since its formation in 1997. Professor Judy Layzer (Urban Studies and Planning) was the featured speaker at the annual induction dinner in October.

### **Carbon Capture and Sequestration Technologies Program**

MITEI's continuing work on carbon capture and sequestration (CCS) technologies focuses on three areas: assessment, education/outreach, and research. Howard Herzog (senior research engineer) leads this effort. Active internal collaborations include Ahmed Ghoniem (Mechanical Engineering) on oxy-combustion and gasification technologies, Alan Hatton (Chemical Engineering) on stimulus-response sorbents for CO<sub>2</sub> capture, Ruben Juanes (Civil and Environmental Engineering) on geologic storage modeling, John Parsons (Sloan School of Management) on CCS regulatory frameworks and business organization, and Mort Webster (Engineering Systems Division) on decision making under uncertainty.

The core of the program is the Carbon Sequestration Initiative, an industrial consortium on carbon management. The 13 members are Alstom Power, the American Petroleum Institute, Chevron, ConocoPhillips, Duke Energy, the Electric Power Research Institute, Entergy, ExxonMobil, Schlumberger, Shell, Southern Company, Suncor, and Vattenfall. The initiative funds research and hosts an annual two-day Carbon Sequestration Forum to examine critical technical and policy issues related to CCS.

Below are some highlights from the past year.

Three patent applications were filed:

C. Botero, R.P. Field, H.J. Herzog, A.F. Ghoniem. Method for Conveying a Solid to a Dense, High Pressure State Via Phase Inversion with CO<sub>2</sub>. Massachusetts Institute of Technology, US Patent Application No. 61/829321, filed 2013.

C. Botero, R.P. Field, H.J. Herzog, A.F. Ghoniem. Method for Preparing a Slurry of Pulverized Solid Material in Liquid or Supercritical Carbon Dioxide. Massachusetts Institute of Technology, US Patent Application No. 61/712954, filed 2012.

Stern, M. C., Simeon, F., Hatton, T. A. Methods and Systems for Carrying Out a pH Influenced Chemical or Biological Reaction. Massachusetts Institute of Technology, US Patent Application No. 20130058857, filed 2013.

The CCS group completed the 2012 Survey of Public Attitudes on Energy and the Environment. This survey has been conducted every three years since its initiation in 2003.

Jan Eide won the Technology and Policy Program best thesis award for “Rethinking CCS—Strategies for Technology Development in Times of Uncertainty.” This is the third thesis from the CCS group in the past five years to win the award (also 2009 and 2012).

In terms of outreach/education, the quarterly CCS regulatory newsletter is published to maintain an online database of CCS demonstration projects, and an annual two-day forum is held.

The group has strong interactions with the national and international CCS communities. For example, it participates in the Coal Utilization Research Council's CCS Technology Collaborative, provides reviews and feedback for the International Energy Agency's CCS Technology Roadmap, and is a member of an international network on CCS costs.

After a 20-year period of significant year-to-year growth in terms of both interest and expenditures, CCS is seeing a slowdown in growth and a probable shrinking in expenditures. The major cause is the disarray in climate policy at both the national and international levels, which creates much uncertainty about the development of commercial markets for CCS technology. Contributing to the problem is the global financial crisis. At present, this has not had a significant impact on the CCS program at MIT but could become problematic if these issues persist for a prolonged time.

Funding for the program comes from diverse sources, including DOE, private industry, and NGOs. Additional information can be found on the program's [website](#).

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