

MIT Energy Initiative

The [MIT Energy Initiative](#) (MITEI) is an Institute-wide initiative designed to help transform the global energy system to meet the challenges of the future. In its first five years of operation, MITEI has attracted more than \$340M from industry and public partners as well as private donors to fund critical energy research and education. The initiative aims to enhance the environmental performance of conventional energy sources and to enable a sustainable energy future through transformational technologies.

FY2011 was another year of institutional growth and expanded activity for MITEI. Key achievements included:

- Building robust research partnerships and networks with 65 industry and public MITEI members
- Attracting sponsored research and other research support totaling approximately \$340M in commitments over five years
- Assuming a key role in the Department of Energy (DOE)–funded Nuclear Energy Innovation Hub led by Oak Ridge National Laboratory
- Supporting through its Seed Fund Program 89 early-stage research proposals, with total funding of more than \$10.7M
- Releasing the final studies *The Future of Natural Gas* and *The Future of the Nuclear Fuel Cycle* to decision makers in industry, government, and non-governmental organizations (NGOs)
- Growing the Society of Energy Fellows to nearly 200 members, with the designation of the 2010–2011 cohort of graduate students representing 19 departments and all five schools
- Growing the energy minor, enhancing the energy educational opportunities for MIT students, and orienting the increasing number of undergraduate and graduate students focusing on energy issues
- Awarding the second round of research awards for the Low-carbon Energy University Alliance (LCEUA), a three-way collaborative research initiative with MIT, University of Cambridge (UK), and Tsinghua University (China)
- Pursuing partnerships in energy education and research with China, India, and the developing world
- Producing, in whole or as cosponsor, more than 30 energy-related seminars, colloquia, and special events, including visits to MIT by Todd Stern, special envoy for climate change at the US State Department, and Arun Majumdar, director of Advanced Research Projects Agency–Energy (ARPA-E)
- Supporting a range of student projects to improve energy and environmental management

- Releasing two major reports from the Associate Programs/Symposium Series: The Electrification of the Transportation System, and The Role of Enhanced Oil Recovery on Accelerating the Deployment of Carbon Capture and Sequestration

MITEI seeks support from partners in industry, private donors, and some public institutions to support a broad portfolio of energy research. For example, the report on the electrification of transport cited above originated at a spring 2010 symposium sponsored by four MITEI associate members. 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 from fossil fuel combustion, and transforming global energy systems.

President Susan Hockfield is actively engaged at the national level in raising awareness of the importance of federal investment in energy research and development in the US. The Institute—with its outstanding students, faculty, and staff; commitment to excellence and innovation; and its exceptional capabilities—is well positioned to make a major contribution to meeting global energy and environmental needs, and the impacts will be enhanced if the pool of energy research dollars were to grow.

MITEI's leadership team includes its director, professor Ernest Moniz (Physics, and Engineering Systems Division [ESD]); deputy director, professor Robert Armstrong (Chemical Engineering [Chem E]); executive director Melanie Kenderdine; and associate director Robert Stoner. The directors are members of the Energy Council, which helps shape MITEI policy directions. The council also includes professor Angela Belcher (Materials Science and Engineering [DMSE], and Biological Engineering), professor Vladimir Bulović (Electrical Engineering and Computer Science [EECS]), Institute Professor John Deutch (Chemistry), professor Leon Glicksman (Architecture, and Mechanical Engineering [ME]), and professor Richard Schmalensee (MIT Sloan School of Management).

The External Advisory Board (EAB) provides strategic direction for MITEI and MIT's energy research. The board, composed of industry, academic, nonprofit, and public sector leaders, is chaired by George Shultz. The board met for the fourth time in October 2010.

Mission

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 conventional energy is produced, distributed, and consumed
- 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

Industry Research Partnerships

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 multi-tiered membership structure enables private-sector partners to sponsor multidisciplinary, multiple faculty "flagship" research programs; contribute to a range of energy-focused MIT laboratories, programs, and centers; support innovative energy concepts from proposals solicited across the campus; participate in MITEI-organized seminars, lectures, and colloquia; and fund critical energy fellowships.

In the past year, MITEI has welcomed two new associate members. Vale is a global mining company working on five continents. ICF International partners with government and commercial clients on large-scale technology solutions in many areas, including energy.

Also in the past year, MITEI selected the sixth group of projects submitted by MIT faculty and senior researchers to receive Seed Fund Program research grants. In the June 2011 round of seed funding, MITEI awarded over \$2M to 17 projects, each lasting between one and two years. The funded projects span 14 departments, laboratories, centers, and institutes and all five schools. Funding for the new grants comes chiefly from MITEI's founding and sustaining members, supplemented by funds from the Chesonis Family Foundation, an anonymous donor, and MITEI. The program supports innovative early-stage research projects addressing energy and related environmental issues. New grants are awarded annually.

Developing Country Initiatives

Associate director Stoner oversees a diverse group of initiatives that focus MIT expertise and involvement in energy-related issues of special interest to the developing world.

Agencia Nacional de Hidrocarburos/Corpropaz Initiative—Colombia

MITEI was invited by members of the MIT-Harvard Club of Colombia to advise club members and leaders of the NGO, Corpropaz on a major project they have proposed in partnership with Columbia's national government to provide livelihoods based on

biofuel production for hundreds of thousands of discharged soldiers and displaced persons. A small faculty team, with expertise in biofuels, transportation infrastructure, finance, and trade travelled to Bogotá in August 2010 to meet with project planners and officials, and to make a preliminary assessment. Over the next two years, a broader group of faculty and students will participate in a series of planning workshops at MIT. The work is being supported by MITEI associate member Agencia Nacional de Hidrocarburos–Colombia.

Nigeria-US Program for Research on Energy, Water, and the Environment

With the appointment of EAB member Ngozi Okonjo-Iweala to the post of Minister of Finance in Nigeria, MITEI has renewed its 2010 effort to establish a long-term partnership for energy education and research with the universities of Africa, and in particular Nigeria, Africa's most populous country. With colleagues from Princeton University, MITEI developed a program framework that would enable MIT and other US universities to participate in collaborative energy research in areas of particular interest to Nigeria and other developing countries. The program, to be titled the Nigeria-US Program for Research on Energy, Water, and the Environment, would be modeled in part on the MIT-Masdar relationship (see below), but focused more narrowly on collaborative research and training funded by the Nigerian government and the World Bank. Discussions are ongoing.

Tata-MIT Center for Engineering and Design Research

At the instigation of President Hockfield and EAB member Sir Ratan Tata, MITEI is helping to shape a proposal for a cooperative program that would connect MIT faculty with the Indian context through postgraduate research. Among the important themes to pursue is the design of products and systems for markets severely constrained by environmental sustainability considerations, inadequate energy supplies, and very limited capital. Much has been done in India and other rapidly developing economies in this context, with an emerging body of work sometimes referred to as "frugal engineering," which has helped to bring the benefits of modernity to many who would not otherwise be able to afford them. MITEI intends to explore and codify the principles of ultra low-cost design, starting with collaborative research at MIT and a new Indian postgraduate institution. Faculty members representing numerous disciplines have responded favorably to this concept. As the proposal is refined, the principals look forward to establishing a program geared toward graduate research and education that would help to advance a promising new field that can bring benefits to the developing and developed worlds.

Solar Energy Research Institute for India and the U.S.

MITEI has facilitated MIT's participation in a consortium led by the National Renewable Energy Laboratory (NREL) in response to the joint call for proposals announced in mid-2011 by DOE and the Indian government. The consortium, focused on low-cost solar energy technologies, will garner \$75M over five years for solar research from both governments, including a 100 percent industry-matching requirement. (The five-year allotment to MIT will be \$1.1M if the consortium's bid is successful.) MIT research projects will address areas of novel earth-abundant solar cell materials (directed by

professor Tonio Buonassisi) and low-cost community-scale concentrated solar power (directed by professor Harold Hemond).

Masdar Institute

MITEI founding public member, the Masdar Institute of Science and Technology, became significantly more active in the last year. The newly created Masdar Seed Fund Research Program awarded a total of \$800,000 to two novel projects in the field of desalination technology. Grant recipients were professors Krippa Varanasi and Alan Hatton. Funding for both projects will be spread over two years, and is accompanied by additional support in Abu Dhabi for a Masdar collaborator.

Masdar Institute also collaborated with MITEI to develop an innovative ten-day energy technology and policy program, offered at MIT in June 2011 for 15 Emirate graduate students. The program was well received and is likely to be expanded in future years.

Low-carbon Energy University Alliance (LCEUA)

LCEUA is a research collaboration among Tsinghua University, the University of Cambridge, and MIT that focuses on low-carbon energy technologies and related policy, with a particular focus on China. LCEUA announced its second round of seed grant awards in March 2011. Four of 13 proposals were funded at the level of \$600,000 per collaborative team for three years. This brings the total awards made by LCEUA in its first two years to \$4.4M. 2011 projects and their principal investigators included the following.

- Superconducting DC power distribution for datacenters and microgrids (Zeng Rong, Tsinghua; Bartek Glowacki, Cambridge; John Brisson, MIT)
- Flexible nuclear power for clean fuels and peak electricity production by co-electrolysis of CO₂ and H₂O (Bo Yu, Tsinghua; Paul Bristowe, Cambridge; Bilge Yildiz, MIT)
- Electrochemical conversion of de-ashed coal in solid oxide direct carbon fuel cells (Ningsheng Cai, Tsinghua; Bartek Glowacki, Cambridge; Ahmed Ghoniem, MIT)
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In parallel with the technology and policy program, researchers at Tsinghua University and the MIT Joint Program on the Science and Policy of Global Change are also collaborating on a special project to analyze China's national economy and its energy system in the context of climate change. Special attention will be given to topics of strategic interest to China, including coal-to-liquid technology and carbon capture, and the evolution of energy demand, notably for personal transportation. This is a five-year, \$2.5M program supported in part by MITEI founding members Eni S.p.A., an Italian multinational oil and gas company, and Shell, and by the global services firm ICF International.

MIT-China Low-carbon Energy Leaders Executive Education Program

MITEI launched the MIT-China Low-carbon Energy Leaders Executive Education Program this year. The program emerged from initial discussions between President Hockfield and Li Yuanchao, head of the Organization Department of the Communist Party of China Central Committee. It seeks to bring Chinese officials and business leaders into contact with Western thinking on important energy-related topics spanning technology, resources, and policy, during a week-long program in a retreat-like setting on the MIT campus. While the objective is to capture the global perspective, the Chinese are especially interested in the US perspective and hope to use what they learn to inform their own economic development strategies and policy.

Under the direction of Professor Moniz and Dr. Stoner, and in cooperation with members of the Antai School of Business at Shanghai Jiao Tong University, the program, consisting of lectures, panel discussions, and company visits, will be offered three times per year for up to three years for groups of 25–30 participants drawn from the top ranks of national and provincial government and business. The first session was held April 18–25, 2011; more than two-dozen MIT faculty participated. A second session is planned for early December.

Education

Catalyzing student 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 discussed below.

MITEI's Energy Education Task Force (EETF) guides the development of energy education at MIT. After serving as task force cochair with Professor Bulović since 2008, professor Donald Lessard (MIT Sloan) stepped down in June 2011 as he began a sabbatical. Amy Glasmeier, professor and chair of the Department of Urban Studies and Planning, assumed cochairmanship of 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 the MITEI Education Office support MITEI and EETF in implementing energy education programs.

Energy Studies Minor

The Energy Studies Minor was launched in September 2009. The minor's multidisciplinary curriculum integrates energy science, social science, and technology/engineering and is open to students from all majors. Thirteen students representing four schools graduated with the energy studies minor in AY2011.

The Energy Minor Oversight Committee (EMOC), a subset of the standing EETF with members from all five schools, is responsible for the intellectual content of the minor. EMOC reports to the Inter-school Educational Council (ISEC)—a governance body consisting of one associate dean from each school, the dean of undergraduate education, and one associate provost—established in 2009 as a three-year experiment. EMOC and ISEC met regularly throughout 2010–2011.

Curriculum Development and Dissemination

A new project-based subject, developed with support of the EETF, 10.27: Energy Engineering Projects Laboratory, debuted in spring 2011. In March, the campus-wide celebration of the 20th MacVicar Day featured faculty and students presenting recent innovations in energy classes, Undergraduate Research Opportunities Program (UROP) projects, and student projects. Four subjects within the energy minor have been published to date on OpenCourseWare (OCW), with five additional subjects scheduled for OCW publication and five in the planning stage.

Energy UROP Projects

MITEI's summer UROP program grew to 29 students (58 percent female) from 11 departments who will work on energy projects during summer 2011. Projects range from the physics of carbon dioxide migration to novel solar energy materials to an energy-harvesting textile façade to an algorithm for wind resource assessment. MITEI summer 2011 UROP projects will be supported by MITEI founding members, which include BP and Shell, three MITEI affiliate members, and four alumni donors.

Graduate Energy Fellows

The Society of Energy Fellows at MIT has grown to nearly 200 members, with the designation of the 2011–2012 cohort of graduate students representing 19 departments and all five schools. The fellowships are supported by a group of MITEI's founding, sustaining, and associate members. The society 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 2010–2011 included an afternoon symposium and poster reception on the eve of MITEI's fall research conference (October 2010), meetings and discussions hosted by sponsors for their groups of fellows, dinner seminars featuring professor Michael Greenstone (Economics) and principal research scientist Una-May O'Reilly (Computer Science and Artificial Intelligence Laboratory), and a range of informal gatherings.

Campus Energy Activities

Over the past five years, the Campus Energy Task Force (CETF) has been advancing president Hockfield's vision of engaging the entire MIT community in campus energy activities. The task force has supported and coordinated a broad community of departments and people—department heads, research scientists, faculty, department staff, custodians, administrative assistants, undergraduate and graduate students, et al.—to help MIT “walk the talk” on energy and sustainability. The campus energy program has provided a guideline and opportunity to impact campus energy use and foster an awareness of energy issues across campus, and to allow many more people to engage with, learn from, and enrich the MITEI initiative in different capacities.

For FY2011, a summary of highlights include:

- Successfully completed the first calendar year of MIT Efficiency Forward—the industry-leading energy conservation and efficiency program to save 34 million

kWh over three years and \$50M over the lifetime of projects. In 2011, MIT surpassed its target energy savings goal by 30 percent.

- To date, achieved campus energy cost savings totaling over \$3.5M annually. Of the total 160,000 MMBTU (million BTUs) saved since 2007, 52,000 MMBTU were saved in FY2011 alone.
- The new MIT Sloan School of Management and the David H. Koch Institute for Integrative Cancer Research buildings were completed and occupied—both are anticipated to achieve a strong Leadership in Energy and Environmental Design (LEED) “gold” rating for sustainable design.
- Over 300 faculty, staff, and student green ambassadors have been recruited to drive sustainable practices in offices, laboratories, and dormitories.
- MIT’s campus transportation program was recognized for its efforts in reducing the rate of employees driving to work alone to 19 percent, thus increasing alternative modes of transportation.
- Campus energy work has provided additional research and learning opportunities for both students and faculty, including campus-focused UROP projects, class practicums, theses, and student projects.
- MIT submitted its first progress report to the Global University Leaders Forum’s (GULF’s) Sustainable Campus Charter, which President Hockfield joined in 2010. The report outlines progress made to advance the charter and shares the Institute’s results with the international community.
- MIT has made strong progress towards DOE’s new Global Superior Energy Performance (GSEP) Partnership to pilot the program’s new building energy management certification program. MIT’s participation in DOE’s Commercial Building Partnerships (CPB) program is deploying national laboratory technical assistance to identify additional energy efficiency strategies on campus.
- MIT’s campus energy program was recognized in 2011 with several national, regional, and local awards.

Energy Conservation, Efficiency, and Sustainable Design

Energy Conservation and Efficiency

From FY 2007 through FY2011, MIT has successfully accumulated over 160,000 MMBTU of annual energy savings from thermal and electrical projects, resulting in over \$3.5M cumulative annual savings. This represents an annual reduction of more than 5 percent of MIT’s total energy use. In FY2011 alone, MIT successfully reduced over 14 million kWh in electricity use, which included work accomplished through the 2010 MIT Efficiency Forward program and additional work completed in FY2011. Of the total 160,000 MMBTU saved since 2007, 52,000 MMBTU were saved in FY2011 alone.

In addition to the savings stated above, Information Services and Technology (IS&T) has fostered use of more efficient equipment and operating practices. Activities in FY2011 included: IS&T participation in the building W91 data center energy efficiency study

as part of DOE's CPB program with the Department of Facilities and the Lawrence Berkeley National Laboratory; promoting individual smarter printing practices and consolidating single function devices to multi-function devices, and implementing "hold and release print" infrastructure to minimize unclaimed print jobs in public Athena clusters; and hosting several seminars and web resources to promote more energy and resource efficient computing and printing.

In January 2011, MIT the Efficiency Forward program concluded its first year of collaboration with very strong success. MIT has exceeded the program's first-year energy savings goal by 30 percent and has surpassed its first-year goal of achieving 10 million kWh of energy savings, which achieved an actual reduction amount of 13 million kWh.

An important component of the Efficiency Forward program is to inform and engage the community and local organizations to adopt similarly focused efficiency programs. On January 11, 2011, President Hockfield and NSTAR chief executive officer (CEO) Thomas May hosted Efficiency Forward: Partnering for Success, a forum to recognize the important role energy efficiency plays in Massachusetts's clean energy economy and to celebrate the strong progress of the MIT/NSTAR collaboration. Those joining President Hockfield and Mr. May in making remarks included Cambridge mayor David Maher, state undersecretary for energy Phil Giudice, and MIT Sloan dean David Schmittlein. A key feature of the forum was a workshop attended by over 100 local business, community, and university leaders to review accomplishments and outline strategies to foster support for broader adoption of large-scale, energy efficiency programs in Massachusetts.

Another priority for the task force was to identify strategies to overcome a principal obstacle for organizations to invest in energy efficiency: access to first-cost capital. MIT established its first revolving energy conservation investment fund with \$2M of seed capital provided by MIT and MIT alumni to fund investments in energy efficiency across campus. The fund is intended to demonstrate that significant energy savings can be realized by using cost-effective integrated solutions and technologies. MIT will use the savings from these projects to fund additional projects. In addition, through its Efficiency Forward program, MIT has demonstrated the value of external partnerships via collaboration with NSTAR to develop a unique funding strategy consisting of leveraging MIT investments with enhanced NSTAR incentive payments and reinvestment of energy savings. This strategy has leveraged nearly \$14M for cost-effective investments in energy efficiency measures.

Sustainable design

In FY2011, the new MIT Sloan School of Management and the David H. Koch Institute for Integrative Cancer Research buildings were completed and occupied—and both are anticipated to achieve a strong "gold" rating from the US Green Building Council's LEED program for their high degree of sustainable design. The design teams used an integrated design process to achieve a greener building that tackles energy use head-on and challenges current conventional rules for heating, ventilation, and air conditioning needs

to improve system efficiencies. The new MIT Sloan and the Koch Institute buildings will use 45 percent and 30 percent less energy, respectively, than typical similar buildings.

Engaging the Entire Community

A Network of Change Agents

The Green Ambassadors Program was established in 2009 to create and empower a network of individuals interested in taking action in their own laboratory, office, or dormitory to promote more sustainable practices at MIT. Focus areas include energy conservation, resource efficiency, green purchasing, alternative transportation, awareness, and outreach. To date, the program has grown to include 300 staff, faculty, and student volunteers to model and promote the Institute's energy and environmental stewardship objectives. CETF members have supported this popular initiative by providing information resources, outreach material, and networking support to share best practices and by hosting workshops.

Building Awareness on Campus

A key component of the campus energy program is building community awareness of campus activities to both inform and expand support and input for its activities. In FY2011, several activities reached out to different constituencies on campus and in the community. Examples include:

- MIT Alumni Leadership Conference session on campus energy progress (October)
- Efficiency Forward Forum event for large, regional energy customers (January)
- Global University Leaders Forum (GULF) Sustainable Campus Charter progress report submitted (January)
- IS&T seminars on energy efficient computing practices (January/May)
- Greening MIT exhibit at MIT150 Open House, Earth Day Fair, and representation at Transportation Fair, Human Resources Staff Engagement Fair, etc. (March/April)
- Tech Reunion alumni panel on sustainable design (June)
- Over 10 news articles written and published on campus energy projects

In January 2010, President Hockfield joined 25 national and international counterparts in signing the World Economic Forum's GULF Sustainable Campus Charter. The charter reaffirms MIT's commitment to embrace sustainable development principles that guide campus operations towards a more energy efficient and sustainable future. This commitment will be a guiding feature in many aspects of campus development and MITEI looks forward to engaging the broader MIT community in shaping progress. In addition, the charter provides an additional platform to engage with and share the initiative's experience with international peer institutions on the important issues surrounding campus sustainability. In January 2011, MIT submitted its first annual progress report to share its activities with the global community.

Improving Transportation Options

Aggressive transportation demand management programs at MIT include subsidized Massachusetts Bay Transportation Authority passes, rideshare, “van pool,” local car-sharing services, and significant investments in bicycle infrastructure. A key metric for measuring transportation program success has shown strong improvements in FY2011: MIT’s proportion of single-occupant vehicle trips, or “SOV rate,” declined to 19 percent, a rate significantly below the state and national average. MIT has also adopted biofuels in its diesel fleet, integrated compressed natural gas, hybrid-electric, and electric vehicles, and moved to higher efficiency vehicles that are “right-sized” for the task.

Student Learning, Research, and Engagement

Using The MIT Campus as a Living Laboratory

MIT’s campus operations are being used as a living laboratory—UROP projects, special classes, internships, and research projects—to foster students’ emerging technical and leadership skills to help define and solve MIT’s own energy challenges. In 2011, several UROP projects and internships focusing on campus energy issues were supported by CETF members in partnership with the academic and administrative units. For example, one campus sustainability UROP project worked with the Environment, Health, and Safety (EHS) Headquarters Office, the vice president for finance office, the MIT Center for Transportation and Logistics (CTL), and Staples, Inc. to assess the MIT community’s interest and preferences in purchasing environmentally preferable office supplies from Staples. Also through CTL, two master’s students in the supply chain management program researched and designed a reusable delivery tote system to be piloted by Staples on the MIT campus to reduce resource use on campus.

Through the MITEI Student Campus Energy Project Fund, MIT has supported over 35 student projects on campus that engage students and advance campus energy objectives while simultaneously providing rich learning opportunities.

Recent student campus projects included a program to bring a wind turbine to campus; development of a real-time, dormitory energy use monitoring system; and the development of outreach and awareness material for promoting more sustainable on-campus catering. Administrative units, including the Department of Facilities and EHS Headquarters Office, continue to support curricular, project-based learning activities by developing and advising campus energy-related projects, including ones for ESD.123 Industrial Ecology, MIT Sloan’s executive education programs, and the freshman pre-orientation program.

CETF faculty members have integrated coursework to address important issues confronting the MIT campus. For example, an MIT Sloan team in the system dynamics group is analyzing the cost and benefits of “green design” features of the new MIT Sloan building. This will provide important input in MIT’s green building program.

A building technology program course developed several class projects to measure and assess different energy efficiency strategies that could be considered for use on MIT’s campus.

CETF has begun discussions with EETF on means to enhance the use of the campus as a learning laboratory for undergraduates in the energy minor and freshman education programs.

Recognition

As campus energy programs become established and results are demonstrated, MIT has been recognized for its accomplishments nationally, regionally, and locally.

MIT accepted an invitation by DOE secretary Stephen Chu to be the only university to pilot the GSEP Partnership—a new DOE-supported, public-private partnership designed to accelerate energy efficiency improvements in commercial buildings and industrial facilities. Recognizing MIT's leadership in campus energy management, DOE chose MIT to pilot GSEP's international certification program to affirm facilities that adopt approved energy management systems and achieve significant and independently validated efficiency improvements over time. MIT's campus energy program was also recognized by DOE with the awarding of a technical assistance grant to participate in its CPB program, which seeks to leverage national energy laboratory expertise in identifying significant energy efficiency strategies on campus.

In addition, MIT received the following awards in FY2011:

- Northeast Energy Efficiency Partnerships, for Business Leader for Energy Efficiency
- City of Cambridge GoGreen Award, in the energy category (and in transportation category in 2009)
- Massachusetts Interfaith Power and Light, for Leading by Example
- Massachusetts Department of Transportation Award, for Excellence in Commuter Options

Looking Forward

CETF over its first five years has established a strong track record of fostering solutions to the “now-term” energy challenges facing large institutions: how to reduce emissions, minimize energy use, and create an informed and engaged community. The task force has leveraged the expertise and experience of staff, faculty, and students to provide a unique complement and integrative space for MITEI's research and education work.

Moving forward, there are several key areas on which to focus and for which resources are needed to enable success:

- CETF will continue to convene with a renewed charge to coincide with cochair Israel Ruiz's replacement of cochair Theresa Stone and the fifth anniversary of MITEI
- CETF envisions more reliance on critical subgroups focused on specific new goals with the full task force acting to integrate these activities

- New goals may include:
 - A faculty-led, long-range campus energy study
 - Joint action with EETF, including exploration of new staff positions to more fully integrate student learning into campus energy programs
 - Developing campus energy program–focused UROP projects sponsored each semester by MITEI
 - Establishing a campus energy-focused research assistant program to support in-depth, faculty-sponsored graduate research into and experimentation on issues affecting institutional energy issues
 - A renewed focus on measurement and verification for campus projects, behavioral change demonstrations, and outreach and education

Outreach

The MITEI outreach group, led by communications director Rebecca Marshall-Howarth, is responsible for producing a wide range of meetings and published materials that have been steadily increasing in type and number in the last five years. For FY2011, the internal listing of public and private events supported by the group included 65 separate meetings, well over one every week. Most are concentrated into the academic year, September through May. The following list, representing about half of these efforts, reports those with a substantial MIT community involvement, as well as a few “invitation only” meetings of specialized interest.

High points of the year included the rollout of four major publications: on the nuclear fuel cycle, the future of natural gas, the electrification of transportation, and enhanced oil recovery in relation to sequestration options. In each case, a panel of authors outlined the findings of the report to both a present and virtual audience via webcast. Virtual participants were invited to join in the question and comment period following the panel presentation. The webcast presentations have been very effective and the outreach group looks forward to organizing more in future.

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.

Colloquia and Symposia

- Arun Majumdar, director, Advanced Research Projects Agency–Energy (ARPA-E)—The energy challenge: Innovation and the role of ARPA-E (October 13)
- Symposium honoring professor David Marks—Complexity and sustainability: Perspectives on environmental technologies and global systems (November 11)
- R. Neal Elliott, associate director for research, American Council for an Energy-efficient Economy—An efficient future for energy use in the built environment (January 10)

- Associate Member Symposium—Variable energy sources: Implications for the grid (April 20)
- Earth Day Colloquium: Todd Stern, special envoy for climate change, US State Department—Talk and action: The role of international negotiations in addressing the climate challenge. Followed by MIT panel—Rethinking climate change: The past 150 years and the next 100 years—moderated by senior lecturer John Reilly, with panelists Professor Moniz and professors Kerry Emanuel, Ronald Prinn, and Christopher Knittel, and senior lecturer Sarah Slaughter (April 21)

Cambridge Energy Research Associates Seminar Series

- Professor Cynthia Rudin: Mitigating manhole events in Manhattan (October 12)
- Soren Hermansen: Samso: Denmark's renewable energy island (November 8)
- Professor Buonassisi: Predictive defect engineering for scalable photovoltaics at \$1/Wp (November 9)
- Juliette Kayyem, US Department of Homeland Security; Peter Neffenger, US Coast Guard: The response to the oil spill and the larger issue of energy and national security (December 14)
- Professor Marija Illic, visiting professor, ESD: Engineering IT-enabled electricity services (February 8)
- Michael McGehee, Stanford University: Organic and dye-sensitized solar cells (March 8)
- Claus Hviid Christensen, Lindoe Offshore Renewables Center, Denmark: Catalysis for H₂ production (April 12)
- Mark Koper, Leiden University, the Netherlands: Catalysis and surface chemistry (May 10)

Special Events

- MIT Energy Futures Conference, Monaco (September 12–24)
- Energy Fellows Seminar, Professor Greenstone (October 6)
- *Nuclear Tipping Point*, film and presentation by EAB chair George Schultz (October 15)
- Microsystems Technology Laboratory/MITEI Workshop: μ Energy: Conversion, storage, and use (December 2–3)
- Dr. Zhengrong Shi, CEO, Suntech Power: The future of solar energy from the perspective of Suntech (December 7)
- Energy Futures Week: Multiple activities as part of Independent Activities Period (January 10–14)

Exploring Careers in Energy (February 3)

- MIT panel members: United Nations Climate Change Conference, Copenhagen (February 5)
- EDF Energy company visit and seminar (February 14–15)
- Siemens smart grid seminar (March 1)
- MacVicar Day 20th Anniversary: Events focusing on energy and education (March 9)
- Brazil-MIT Forum on energy, environment, and policy innovation (April 14–15)
- Henry W. Kendall Memorial Lecture: Lisa Jackson, Environmental Protection Agency (April 15)
- China Executive Education Conference (April 18–26)
- MIT Earth Week: MITEI activities, including Earth Day Colloquium (April 19–22)
- William Tumas, director, Center for Chemical and Materials Science: Overview of NREL solar energy programs and capabilities: Sunshot, solar thermal, and solar fuels (April 29)
- MITI50 celebration and open house (April 30)
- Lieutenant Colonel Stephen Wooldridge, Commander, U.S. Army Health Facility Planning Agency: Sustainability and evidence-based design (May 3)
- MITEI on the Road: New materials for solar capture and storage (alumni events in southern and northern California, May 17–18)
- Masdar student program, by invitation (June 18–30)

Press Events

- Rollout of The Future of the Nuclear Fuel Cycle summary report (September 16)
- Rollout of The Future of Natural Gas interim report (September 16)
- Briefing: Signing of MIT-Shell partnership (October 13)
- Briefing: Opening of Eni-MIT Solar Frontiers Center (October 18)
- Briefing: Ferrovia joins MITEI (December 2)
- Rollout of The Electrification of the Transportation System report (January 13)
- Rollout of The Future of the Nuclear Fuel Cycle report (April 28)
- Rollout of The Future of Natural Gas report (June 9)

Publications

Energy Futures, MITEI's semiannual magazine, edited by Nancy Stauffer, conveys the high points of MITEI activities to an even wider audience. MITEI also produced a volume of the 2010 research, education, and outreach spotlights featured on the MITEI

website and news office home pages. In addition, the monthly e-newsletter, inaugurated last year, now has 4,000 subscribers. It updates the community on MITEI activities and progress, particularly events welcoming public involvement.

As web-based activities become more complex and demanding, this year MITEI hired a webmaster to oversee the daily maintenance and update of the site and to spearhead a comprehensive redesign, which will launch in November 2011. In the process, other design elements of MITEI publications will also be coordinated to reflect changes at the initiative.

The outreach group also edited and produced the three reports *The Future of the Nuclear Fuel Cycle*, *The Future of Natural Gas*, and *The Electrification of the Transportation System*. Each is available on the MITEI website or in hard copy.

Laboratory for Energy and the Environment

The Laboratory for Energy and the Environment (LFEE) is a key subunit within MITEI that deals with energy, the environment, and sustainability. It includes both core component and affiliated programs; highlights of 2010–2011 achievements are detailed below.

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. Senior research engineer Howard Herzog leads this effort.

The core of the program is the Carbon Sequestration Initiative, an industrial consortium on carbon management. The 18 members are Alstom Power, American Electric Power, American Petroleum Institute, Chevron, ConocoPhillips, Electric Power Research Institute, Enel, Entergy, ExxonMobil, Marathon Oil, Peabody Energy, Sasol Technology, Schlumberger, Shell, Siemens Power Generation, 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 is a listing of recent research project areas:

- [Strategies for implementing CCS at coal-fired power plants](#)
- [Policies for promoting innovation in CCS](#)
- [Methodology for uncertainty analysis of capacity estimates and leakage potential for geologic storage in saline aquifers](#)
- [Modeling of cost and performance of CCS plants in the Western Interconnection](#)
- [Costing CCS technologies](#)
- [Comparison of solvents for postcombustion capture of carbon dioxide by chemical absorption](#)
- [Stimulus-responsive structure fluids for dynamic mediation of carbon dioxide separation](#)

Representation of CCS technology in emissions predictions and policy analysis

The feasibility of air capture

- Development of a carbon management geographic information system
- Survey of public attitudes about carbon dioxide capture and storage
- Regulatory and legal issues for carbon dioxide capture and storage

A few highlights of the past year include:

- Howard Herzog won the 2010 Greenman Award from the International Energy Agency Greenhouse Gas Research and Development Programme “in recognition of contributions made to the development of greenhouse gas control technologies.” (September 2010)
- Howard Herzog was a member of a CCS leadership delegation to China sponsored by the Clean Air Task Force (November 2010)
- New research projects were launched in the following areas:
 - Water-energy nexus and its implications for CCS
 - Negative emissions from biomass plus CCS
 - Flexibility of CCS power plants for load following

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

Analysis Group for Regional Energy Alternatives

MITEI 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 other related projects, 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 the local energy system operations, and 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 projects include projects in the MIT-Portugal program’s sustainable energy systems focus area, most notably the Azores Green Islands Project. AGREA’s bottom-up approach helps both policy makers and private sector innovators identify new market niches for clean energy technologies. Other past projects have focused on New England; Shandong, China; Mexico City; Northern Europe; Switzerland; the UK; Argentina; as well as ongoing work in Portugal and the potential offshore wind market in the U.S.

In addition to the projects and programs listed above, director Stephen 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; 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 program [website](#).

Affiliated Groups

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

Building Technology Program

Research in the Building Technology Program (BTP) has its principal focus on energy efficiency and sustainable design for buildings. In the US, buildings consume almost 40 percent of the total energy and more than two-thirds of the electricity. Their long life and the difficulty of renovation mean that mistakes in today's buildings will create energy and environmental problems for much of this century. In many instances, investment in retrofitting buildings with new energy efficiency technologies is more cost effective than investment in new energy production facilities. If done properly, energy efficient and sustainable design will also lead to better indoor health, comfort, and productivity.

All five faculty members of BTP have had strong input into LFEE's or MITEI's energy research and teaching: Professor Glicksman and professors Marilyne Andersen, John Fernandez, John Ochsendorf, and Leslie Norford (all Architecture). Professor Andrew Scott (Architecture) is also a member of the group and is active in many projects. Many of the activities involve substantial joint efforts with faculty members and students in EECS, Civil and Environmental Engineering (CEE), and Mechanical Engineering (ME), as well as the Harvard School of Public Health; the city of Cambridge (UK); Chalmers University of Technology; the Swiss Federal Institute of Technology; and Tsinghua University. Typically 20–25 graduate students are involved in building technology research at any given time. Some students receive degrees in the Department of Architecture and others in the School of Engineering. BTP faculty and students are working on major projects on the natural ventilation of commercial buildings; design tools; fault detection, monitoring, and control; sustainable buildings for developing countries; daylighting; industrial ecology; and the application of option theory. They are also working with the MITEI campus energy management and education task forces. Currently, there are joint programs with researchers and academics in Portugal, Singapore, Abu Dhabi, and Japan. Professor Andersen is taking a tenured position in the École polytechnique fédérale de Lausanne (Switzerland) next year.

Center for Advanced Nuclear Energy Systems

In fall 2010, MITEI released a summary of *The Future of the Nuclear Fuel Cycle*, a large interdisciplinary study of the fuel cycle; the study was managed through the Center for

Advanced Nuclear Energy Systems (CANES). Charles Forsberg is executive director of the study, initiated in 2008 to examine the pros and cons of various fuel cycle options to enable nuclear power to play a significant role in future energy supplies. Professor Moniz and professor Mujid Kazimi cochaired the study, which involved 10 other faculty members and approximately 12 graduate and undergraduate students.

CANES develops research concepts for nuclear energy systems promising more favorable economics, safety, proliferation resistance, and environmental impact. The center's programs involve development and application of methods for the design, operation, and regulation of current and advanced nuclear reactors and fuel cycles. Professor Kazimi is the founding and present director of CANES. Information on the center's extensive research and outreach activities is available at the center's [website](#).

Sloan Automotive Laboratory

A significant amount of MITEI's research volume supports work at the Sloan Automotive Laboratory (SAL). Many of SAL's projects involve quantitative and cross-disciplinary study of the complex energy and environmental issues created by use of transportation propulsion and vehicle technologies and fuels. SAL is directed by professor Wai Cheng, with participation from professor John Heywood, principal research engineer Tian Tian, and principal research scientist Victor Wong all from ME; and professor William Green from Chem E. It continues to pursue promising research to improve powertrain performance, efficiency, and fuel utilization in internal combustion engines and reduce adverse emissions.

The research at SAL is supported significantly by three consortia, which offer long-term research programs. Funded by companies in the automotive and petroleum industries, the Engine and Fuels Research Consortium explores fuel economy opportunities and critical emission formation mechanisms in internal combustion engines. The Consortium on Lubrication in Internal Combustion Engines involves major engine component and lubricant manufacturers in addressing issues in oil consumption, wear, and engine friction reduction. The Consortium to Optimize Lubricant and Diesel Engines for Robust Emission After-treatment Systems has been established to develop low ash-producing lubricants to enable significantly improved diesel emissions control. Besides these consortia, there are substantial research projects with individual sponsorship from different companies and DOE. Examples are low temperature combustion and homogeneous-charge-compression-ignition concepts, diesel fuel detergency, and high-speed lubrication for Formula One engines.

SAL researchers are also involved in multidisciplinary studies assessing new vehicle and propulsion system technologies for future road transportation use. A multisponsor study has examined the potential for more efficient engines, transmissions, vehicle weight reduction, and new fuel streams, such as ethanol to reduce US and European fuel consumption and greenhouse gas emissions. It recently issued a major policy recommendation for cutting the transportation petroleum use and greenhouse gas emissions in the U.S.

Center for 21st Century Energy

The Center for 21st Century Energy is dedicated to developing technologies for a sustainable energy future. The center brings together existing and new energy research programs carried out in ME's laboratories and programs. These include the Electrochemical Energy Laboratory, the Energy in Buildings Program, the Reacting Gas Dynamics Laboratory, the Rohsenow Heat and Mass Transfer Laboratory, SAL, and the Laboratory for Manufacturing and Productivity. The center collaborates with energy researchers in other units and is among the major participants in MITEI. Its research encompasses renewable energy, energy efficiency, carbon management, transportation, and environmental conditioning.

The center's research focuses on technologies for efficient and clean energy conversion and utilization, ground, water and some aspects of aerospace propulsion, aiming to meet the challenges of rising energy demands and prices and the concomitant environmental impact. The program encompasses existing and emerging technologies at the systems, engineering, and scientific levels, including engines and combustion, thermoelectricity, fuel cells and batteries, solar energy and wind power systems, energy efficient buildings, carbon capture, biomass and bio-energy, hydrogen and alternative fuels, and water purification and desalination. The center's director is professor Ahmed Ghoniem, and faculty participants include Professors Cheng, Heywood, Varanasi, Buonassisi, and Glicksman, and professors John Brisson, Ernest Cravalho, Alexander Mitsos, Eli Sachs, John Lienhard, Gang Chen, Yang Shao-Horn, Paul Sclavounos, Cullen Buie, and Evelyn Wang. A brief description of the different research areas follows.

Solar Energy

New approaches to the design and manufacture of solar cells to reduce their cost are important focus areas in solar photovoltaics. Center participants are developing novel approaches to engineer low-cost, naturally abundant materials that can be manufactured into defect-tolerant, high-efficiency devices. They work on nanostructured solar thermoelectric and thermophotovoltaic materials and devices, combined heat and power in concentrated solar thermal electrics, and optimal system design. Work on concentrated solar thermal systems includes addressing the storage challenges as well as engineering antifouling surfaces for mirrors and collectors and hybridizing solar with other renewable and fossil resources.

Wind Energy

Energy generated from floating offshore wind farms is the next frontier in wind energy. Innovative and economical wind turbine floaters are being developed for deployment in large-scale offshore wind farms in water depths up to several hundred meters.

Carbon Capture

More than 85 percent of primary energy currently comes from fossil fuels, a percentage that is unlikely to change soon. Capture and storage of carbon dioxide from power plants and fuel production facilities is necessary for mitigating global warming. The program's objective is to provide the knowledge base and engineering science for enabling CO₂ capture, including research on gasification of solid fuels (including

biomass), technologies related to the integrated gasification combined cycle, oxy-combustion technologies for solid and gaseous fuels, systems integration and optimization, syngas utilization, and novel gas separation technologies including ion transport membranes and chemical looping. The program works on the production of hydrogen and its liquefaction and storage.

Transportation

In transportation, the major challenge is to increase vehicle fuel economy, reduce emissions, and initiate the transition to nonpetroleum fuels. The program is working on improving combustion engines, developing viable fuel-cell and advanced battery systems, and exploring innovative approaches to using hydrogen in engines and fuel-cell-powered vehicles.

Modeling and Simulations

Advanced modeling and simulations are prerequisites for developing control technology to optimize energy and propulsion system performance, including stability, emissions, efficiency, and power density. This group works on the development and application of advanced simulation methodologies for reactive flows focusing on dynamics, control-oriented models, and implementation of adaptive control algorithms, including sensing and actuations.

Batteries and Storage

Energy storage is a significant enabler for expanding the use of renewable energy and for electrification of the transportation system. Faculty members are involved in developing fundamental knowledge of efficient and higher energy density lithium ion batteries. This program works on investigating mechanisms governing the performance of fuel cells for transportation and electricity generation. Research includes catalysis of small molecules such as oxygen reduction and water splitting, polymeric materials for ion transport, simulation of transport-electrochemistry interactions, and electrolytic and photoelectrochemical cells.

Biomass and Bio-energy

To meet the mandate of using more bio-derived fuels in the transportation sector, there is need to expand the bio-feedstock in a sustainable way and to utilize compatible conversion technology options. Thermochemical conversion using different combination of low temperature pyrolysis and intermediate to high temperature gasification is the gateway to significantly expand the bio-feedstock options and better control the produced fuel quality. Modeling and simulations, thermochemistry, transport and dynamics of gasification are active research area in the center.

Building Technology

In terms of environmental conditioning, per capita energy use in the United States is among the highest in the world, in part because per capita space usage is also high. One important challenge is to apply environmental conditioning only to necessary regions within a space, rather than uniformly throughout the space. The program's work on

small cryogenic systems can provide precision cooling to small areas, and this work is being expanded to scales and temperatures suitable for cooling electronics, sensors, and personal spaces.

Microtechnology and Nanotechnology

Faculty members are engaged in fundamental research on transport phenomena at the macroscale and microscale levels, including enhanced heat transfer, high heat flux heat transfer, and microscale and nanoscale heat and mass transport with applications to a range of issues such as advanced water purification and desalination through thermal and membrane-based processes. Today's clean water production technologies require orders of magnitude of more energy than theoretically required; the objective is to significantly improve their efficiency and economies. The program is also exploring the opportunities for thermoelectric energy technologies. Work has been initiated on advanced materials wherein, by exploiting nanoscale phenomena and technology, new precision applications to energy conversion may be feasible.

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 by MITEL, the Department of Economics, and the MIT Sloan School of Management. The center receives financial support from corporate sponsors and government agencies. CEEPR is directed by Professor Schmalensee.

CEEPR research has a number of focuses, 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 senior lecturer Reilly and Professor Prinn, the program draws on MIT's traditional strengths in science and economics to conduct the interdisciplinary work needed to provide a basis for global climate policy. The 20-year-old program is a world-leading center for integrated assessments of the climate threat and efforts to deal with its consequences. Researchers have developed the MIT Integrated Global System Model to analyze the behavior of the climate system and assess policy proposals. An interdisciplinary team of faculty, professional staff, postdoctoral fellows, and graduate students conducts the work, and the program produces a continuing flow of reports, articles, student theses, and professional and public presentations on the science and policy of climate and other aspects of global environmental change. The work is supported by eight US government agencies; 40 corporations and industry organizations in North America, Europe, and Japan; and one foundation.

Martin Family Society of Fellows for Sustainability

Twenty-three advanced graduate students from 12 departments have been selected for the 2011–2012 Martin Fellows cohort. More than 260 doctoral students from all five schools and more than 25 departments have been supported by the Martin Family Society of Fellows for Sustainability (part of LFEE) since its formation in 1997. In September 2010, 20 current and past Martin Fellows participated in the annual Martin Fellows retreat, which was held at Joppa Flats Wildlife Sanctuary, in Newburyport, MA. This year’s retreat, which focused on coastal and avian ecology, was also attended by Casper Martin of the Martin Family Foundation, as well as leaders of several environment and sustainability student groups. Professors Philip Gschwend (CEE) and Donald Sadoway (DMSE) were featured speakers at Martin Fellows events during the year.

Ernest J. Moniz

Director

Cecil and Ida Green Professor of Physics and Engineering Systems