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 full year of operation, MITEI has attracted more than $200 million from industry and public partners as well as private donors to fund critical energy research and education to enhance the environmental performance of conventional energy sources and to enable a sustainable energy future through transformational technologies.

Fiscal year 2007 was a year of institutional growth for MITEI. Key achievements included:

- Building robust research partnerships and networks with 27 industry and public MITEI members
- Developing sponsored-research support totaling approximately $200 million in commitments over five years
- Funding 31 novel or early-stage research projects submitted by faculty and senior researchers from across the campus
- Establishing the Society of Energy Fellows, which includes 39 graduate students its inaugural class
- Developing a coordinated and multidisciplinary set of energy curricula at MIT, including a major focus on establishing the first energy minor at the Institute
- Establishing the Eni-MITEI Solar Frontiers Research Program
- Sponsoring numerous energy seminars and colloquia
- Launching three new integrated, multidisciplinary energy studies on the future of solar energy, the future of natural gas, and advanced nuclear fuel cycles; and
- Supporting a range of student projects to improve energy and environmental management of the MIT campus

MITEI seeks support from partners in industry, from private donors, and from 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 between academia, industry, and government is essential for meeting global energy needs, addressing climate change from fossil fuel combustion, and transforming global energy systems.

MIT and other universities have also been very concerned that the government is underfunding energy research and development, which is crucial to our energy future. Many independent studies have already called attention to this problem. President 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 and faculty, its commitment to excellence and innovation, and its outstanding capabilities, will surely make a major contribution to meeting global energy and environmental needs if the pool of energy research dollars grows to meet this need.

MITEI is administered by director professor Ernest Moniz (Physics, Engineering Systems), deputy director professor Robert Armstrong (Chemical Engineering), and associate director for strategic planning Melanie Kenderdine. The directors are members of the Energy Council, which helps shape MITEI policy directions and also includes Professor Angela M. Belcher (Materials Science and Engineering and Biological Engineering), Professor Vladimir Bulovic (Electrical Engineering and Computer Science [EECS]), Institute Professor John M. Deutch (Chemistry), Professor Leon R. Glicksman (Architecture and Mechanical Engineering [ME]), Professor Michael Greenstone (Economics), and Professor Rebecca M. Henderson (the MIT Sloan School of Management).

An external advisory board provides strategic direction for MITEI and MIT's energy research. The board, comprised of industry, academic, nonprofit, and public sector leaders, is chaired by George Shultz. The board met for the first time in January 2008.

Mission

MITEI is designed to mobilize the research capabilities of the Institute to help meet the world's most pressing energy challenges. The MITEI interdisciplinary research program and related education and campus-wide activities (discussed in detail below) 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

To achieve its objectives in these energy focus areas, MITEI has established four initiative components: industry research partnerships; education; campus energy management; and outreach.

Industry Research Partnerships

Consistent with MIT's historic engagement with industry, the 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 key strategic objectives. A multi-tier 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; 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:

Founding Members

- BP Technology Ventures
- EnI SpA

Sustaining Members

- ABB Research Ltd.
- Robert Bosch GmbH
- Fundacio Barcelona Tecnologia (b_TEC)
- Chevron USA
- ENEL Produzione S.p.A.
- Ford Motor Company
- Schlumberger Technology Corporation
- Total

Sustaining Public Members

- Portuguese Ministry of Science, Technology, and Higher Education

In addition, 14 firms have joined as associate or affiliate members. Each category of membership is involved in MITEI activities in different ways.

In January 2008, MITEI selected the first group of projects to receive the newly established Seed Fund Program research grants and Ignition grants. Thirteen Seed Fund projects were selected from 54 applications. In September 2008, 17 more projects will receive funding in the second round of the Energy Seed Fund Program. The Program supports innovative early-stage research projects addressing energy and related environmental issues and is supported by pooled funds from MITEI members as well as by private donors such as the Chesonis Family Foundation. Ignition grants were awarded to six junior faculty members to help them develop their work in the energy area. In all, the grants from the first round totaled $1.94 million; second-round grants will total $1.75 million. New grants will be awarded twice annually.

Eni-MITEI Solar Frontiers Center

In March 2008 the Italian energy company Eni officially became a founding member of MITEI. The centerpiece of this major energy partnership is the Eni-MITEI Solar Frontiers Center, which focuses on the development of advanced solar technologies from novel photovoltaic materials to the design of solar power plants. Eni's founding member commitment of $50 million over five years will include $25 million for the center.

The Eni-MITEI Solar Frontiers Center will include five focus areas:

- Nanostructured thin film photovoltaics
- Self-assembling photovoltaic materials
- Water splitting
- Materials for solar energy capture and storage
- Maximizing the return on investment for solar thermal plants

Professors Daniel Nocera (Chemistry) and Vladimir Bulovic have been named the first codirectors of the program.

Another element of Eni's founding member research portfolio will be the investigation of evaluation methodologies for the commercial potential of energy start-ups and novel energy technologies.

The Solar Revolution Project

While not formally a part of MITEI, the Solar Revolution Project (SRP) funded by a $10 million dollar gift from the Chesonis Family Foundation, will form an important part of a growing solar research cluster at the Institute and help leverage MITEI-supported programs. The objective of SRP is to transform solar power from a "boutique" option to an affordable, dependable, large-scale energy solution through research into innovative materials and systems. The Chesonis Foundation will initially support 30 energy fellowships for students in a wide range of solar-related studies. The gift also supports the recently announced major interdisciplinary study of the future of solar power led by Professor Deutch, a study that will be completed under the MITEI auspices. In addition, the Chesonis Family Foundation contributed $500,000 to the MITEI Energy Seed Fund Program for FY2007.

Researchers in the Eni and Chesonis solar initiatives interact with two other programs—the MIT-Fraunhofer Center for Sustainable Energy Systems and the Masdar Foundation solar project—as well as a range of other solar research grants to MIT.

Education

Catalyzing student knowledge and enthusiasm to solve technologically, socially, and politically challenging problems is a central component of MITEI. Education is closely integrated with MIT's energy research and "walk the talk" activities discussed below.

MITEI has established an Energy Education Task Force (EETF) which is cochaired by Professor Bulovic and Professor Donald R. Lessard (MIT Sloan School of Management). It includes 12 faculty members from 10 different departments and three students. The current goals of this task force are to assess MIT's existing graduate and undergraduate energy curricula; develop an undergraduate energy minor; and establish and communicate a model for interdisciplinary energy education at MIT. The EETF meets on a regular basis to provide MITEI with direction on student, faculty, and curriculum needs relative to energy.

Energy education at MIT is cross-disciplinary, addresses both fundamental and applied knowledge, and includes offerings from the undergraduate first year through advanced

graduate study. More than 70 subjects offered across all five schools have a substantive connection to energy issues. A wide range of topics are covered, from subjects with a deep science and technology focus, to those emphasizing economics and policy, to those with hands-on, lab-based, and project-based components. In many cases environmental concerns and impacts associated with energy supply and consumption are discussed as well. New energy subjects are being developed each semester, and the MITEI database (at energyclasses.mit.edu) provides an up-to-date view of these.

This past spring, MITEI named its first group of Energy Fellows—39 graduate students representing 18 departments and all five schools. The fellowships are supported by two founding, eight sustaining, and one associate member. The Society of Energy Fellows at MIT will play a key role in MITEI's intellectual and educational mission by cultivating a community of doctoral students with a wide range of disciplinary perspectives and talents focused on a common set of energy challenges. Society-sponsored activities throughout the academic year will expose Energy Fellow members to a broad range of topics, ideas and points of view—providing them with a breadth of understanding that will serve them well both at MIT and as future leaders in transforming the global energy marketplace. The Society of Energy Fellows will also foster interaction among fellows and between fellows and their sponsors and in so doing expand and enrich the community of students, faculty, staff, and sponsors engaged in energy research, education, and outreach.

Campus Energy Management

The MIT community has embraced the challenge of improving sustainable energy practices on campus, with a specific focus on energy efficiency and conservation. MITEI's Campus Energy Task Force (CETF) has been the catalyst for a partnership between students, faculty, and staff of the Institute. The CETF is cochaired by Professor Glicksman and MIT vice president and treasurer Theresa Stone and includes faculty members from the five academic schools, representatives from key administrative offices and support staff, and both undergraduate and graduate students.

The CETF is developing an innovative campus energy program that seeks to use the MIT campus as a learning laboratory to develop and showcase leading approaches for significantly reducing energy use and greenhouse gas emissions through campus-focused research, student learning opportunities, and the implementation of best practices. The program is developing a platform to engage the entire campus community to identify, develop, and implement sustainable energy practices.

The MIT Campus Energy Program has three goals:

- Reduce MIT's energy consumption and associated greenhouse gas emissions economically
- Enhance student energy education by using the MIT campus and its operations as a living laboratory for discovery and innovation
- Serve as a model of intelligent, effective actions to reduce energy consumption and greenhouse gas emissions, a model that could be used by others in the US and worldwide

CETF concluded its third semester with progress made in focal areas including facilities energy conservation and conservation funding, transportation, efficient computing, behavior change, student learning and engagement, outreach, and fundraising.

Investing in Facilities Energy Conservation

This past year, the CETF has focused on developing a robust, fiscally disciplined program targeting energy conservation investments across campus. Emphasis has been placed on measures that will have a substantial impact on energy consumption and CO_2 generation and at the same time offer economic rates of return.

The Campus Energy Conservation Fund: Through a partnership of students in an MIT Sloan School of Management subject and the Department of Facilities, a $14 million portfolio of investments in campus energy efficiency with a three-year payback has been identified. As a result of this work, the Office of the Executive Vice President launched the pilot phase of the MIT Energy Conservation Investment Fund with $500,000 of seed capital. Savings that are realized from these investments will be reinvested in additional conservation projects, driving continual improvement and investment. This approach has generated attention from the alumni community, and MIT has secured its first alumni donation to the program for an additional $500,000.

Facilities Energy Conservation and High Performance Building Design: The Department of Facilities has made significant progress in designing and carrying out a series of measures to conserve energy and promote sustainable design. Highlights include: implementation of continuous building commissioning programs in Buildings 18 and W35, resulting in over $500,000 of annual energy cost savings; successful completion of a steam trap renewal program for academic and housing buildings; initiation of several lighting efficiency upgrade projects; approval of the Brain and Cognitive Sciences Complex for a Leadership in Energy and Environmental Design (LEED) Silver certification; employment of integrated design for the new MIT Sloan School of Management building (currently under construction) that will likely make it the most energy efficient building on the campus as a result of employing an integrated design from the outset; opportunities for a Silver or possibly Gold LEED certification for New Ashdown House (NW35).

Campus Transportation Initiatives

As transportation needs for the Institute comprise a significant source of energy use and greenhouse gas emissions, the Task Force has begun to consider measures that can have favorable impacts on our campus fleet, commuting options and patterns, and air travel for business. To promote increased ridership in commuter rail service, MIT has recently rolled out a series of enhancements to its MBTA pass and parking programs to reduce the cost of monthly commuter rail passes to the MIT community.

Efficient Campus Computing: Information Technology Energy

The energy impact from the use of information technology and services on campus is substantial. To identify measures that can reduce those impacts and advance more sustainable practices, the Task Force has supported the energy program efforts of

Information Services and Technology (IS&T). Some highlights include: development of programs to promote the use of energy efficient power management features on personal computers; development of personal computer procurement guidelines to increase the purchase of more efficient 80Plus power supplies; promotion of duplex printing in Athena clusters in partnership with students of Share a Vital Earth; and the deployment of two more energy efficient IS&T service vehicles to respond to service calls and laptop deliveries on campus: a pedal-powered tricycle and a gas-electric Ford Escape hybrid.

Behavior Change Programs For Energy Conservation

The Task Force recognizes that there are significant opportunities for improving campus energy efficiency by active participation of individuals, lab groups, and departments. A major focus of the Task Force is identifying behaviors that, if changed, could create opportunities for smarter and reduced energy consumption.

Building Learning Opportunities and Securing Student Engagement

The Task Force seeks to provide opportunities to engage students in the work of the Campus Energy program that provide rich learning and educational experiences while also contributing valuable research, analysis, and project implementation. These opportunities are found both within and outside MIT's curricula and allow students, faculty, and staff to engage in hands-on research and exploration using the operations and management of our own campus infrastructure as a rich test bed of ideas and approaches. Some highlights include:

- Awarding 20 Student Campus Energy Project Grants totaling approximately $20,000
- Sponsoring more than a dozen Campus Sustainability Undergraduate Research Opportunities Projects (UROPs) investigating MIT's energy and environmental performance. Partnering faculty advisors with key campus operations professionals, this UROP program provides real world learning opportunities while providing key research and analysis to our operations divisions.
- Regularly coordinating hands-on student internships that advance our campus environmental stewardship objectives

Fundraising

The Task Force has identified two major areas for fund-raising related to the campus energy effort: educational opportunities tied to the campus energy activities and an investment fund for energy efficiency improvements in the campus infrastructure. Several fundraising activities are currently underway to support these priorities.

Outreach

MITEI's outreach efforts are primarily designed to enhance MIT's role as an as an "honest broker" in framing and analyzing important energy-related societal issues with significant scientific and technological content. Large, multidisciplinary energy studies conducted by the Institute have had major impacts on public policy debates and are viewed by energy policy makers as highly credible, unbiased analyses of key energy

topics. The first two studies addressed options for nuclear power and the use of coal. In the coming year, MITEI will host a comparable study on solar energy, led by Institute Professor John Deutch.

During the last fiscal year, MITEI has hosted seminars and colloquia led by distinguished speakers who discussed many energy-related topics. These included:

- "Clean Energy for the Commonwealth," Deval Patrick, governor of Massachusetts, April 22, 2008
- "Energy Supply and Demand, Economics, and Greenhouse Gas Management: Are They Related?," Carl Bauer, director, DOE National Energy Technology Laboratory, February 26, 2008
- "The New Energy Reality," Clay Sell, deputy secretary and chief operating officer, DOE, January 17, 2008
- "Escaping from Our Energy Trap," Leonardo Maugeri, group senior vice-president for strategies and development, Eni SpA, Italy, January 14, 2008
- "Climate Change: The Economics of and Prospects for a Global Deal," Sir Nicholas Stern, FBA, IG Patel Professor of Economics and head, India Observatory within the London School of Economics' Asia Research Centre, November 19, 2007
- "Facing the Hard Truths about Energy: A Comprehensive View to 2030 of Global Oil and Natural Gas," Lee R. Raymond, retired chairman of the board and chief executive officer of Exxon Mobil, November 6, 2007
- "US Energy Security Policy and the Strategic Petroleum Reserve," Melanie Kenderdine, associate director for Strategic Planning, MITEI, September, 2007

During Independent Activities Period, 2008, MITEI also sponsored "Energy Futures Week: Innovation, Research, and Education for a Sustainable Future." The week of activities included:

- "MITEI: A Peek Under the Hood," a panel discussion of MITEI's role and its work around and beyond the Institute
- Leonardo Maugeri's speech on the financial, political, and social implications of the dependency on fossil fuels
- an "Energy Education Blitz" previewing spring energy-related classes and invitation for student input on future energy academics
- a three-day energy entrepreneurial class, Energy Ventures for Technologists, by Technologists, organized by the MIT Energy Club
- a Campus Energy Showcase featuring posters of student campus energy projects to reduce MIT's energy and environmental footprint
- a "Campus Energy Roundtable," in which Professor Glicksman moderated a panel of MIT faculty and staff in an open discussion of the vision for an energy-efficient campus of the future
- Clay Sell's presentation on the new energy reality

In April, US Senator Jeff Bingaman (D-NM), chairman of the Senate Committee on Energy and Natural Resources, gave the 2008 Karl Taylor Compton lecture on "Forging a Clean Energy Future." Following his presentation, Senator Bingaman participated in a discussion of energy and innovation challenges at an MITEI affiliate member Energy Salon. Organized by the MIT Energy Club, the salons are designed to enable affiliates to meet and share views with important decision makers in the energy field. Following an address to an MITEI colloquium, Carl O. Bauer, director of the DOE's National Energy Technology Laboratory, was also a featured guest at an Energy Salon in February 2008.

MITEI has entered into an agreement with CleanSkies.tv, an online news network covering energy and environmental news, information, discussion, and commentary targeting decision makers. The Initiative will be a portal through which the station gains access to newsworthy energy-related events and activities at the Institute. CleanSkies carried Governor Patrick's speech live.

The MITEI website was expanded to more fully describe and link to energy research, education, and applied activities throughout MIT. It also includes special access to MITEI members.

In the past year, the Initiative also produced the first edition of a new MIT magazine, *Energy Futures*, edited by Nancy Stauffer. This publication, to appear semiannually, reports on research results and energy-related activities across the Institute.

Laboratory for Energy and the Environment

The Laboratory for Energy and the Environment (LFEE) is a key sub-unit within the MIT Energy Initiative. It includes both core component and affiliated programs; highlights of 2007–2008 achievements are detailed below. In addition to these programs, the Summer Air Quality Symposium Series held annually at Endicott House is also affiliated with LFEE. Proceedings of the 2008 symposium are posted at http://lfee.mit.edu/.

Alliance for Global Sustainability

Research and educational activities supported by the Alliance for Global Sustainability (AGS) connect scholars from four partner universities—MIT, the Swiss Federal Institute of Technology (ETH), the University of Tokyo (UT), and Chalmers University of Technology, Sweden—with stakeholders from industry, NGOs, government, and other leading academic institutions addressing complex environmental problems transcending geographical and disciplinary boundaries.

Building on past integrated, collaborative research activities, AGS has inaugurated a large-scale research program focused on near- and medium-term energy scenarios. The first Flagship Program, Near-Term Pathways to a Sustainable Energy Future, is comprised of a set of regional projects that focus on key energy sectors. In addition, work on the MIT Portugal Program on Sustainable Energy Systems has focused on a major initiative on urban futures. A Green Island Program focused on the Azorian Island of Sao Miguel will work not only on new research in the integration of sustainable energy technologies and management schemes but will also develop demonstrations to serve as a test bed for deployment in larger communities. These projects are looking

in detail at how alternative portfolios of technologies and policies can affect the development of a region's energy infrastructure.

AGS has already invested in sustainability-focused energy research and can present a credible worldwide analysis while at the same time providing a neutral forum for the development of integrated scenarios that will require political and regulatory action. To increase the profile of AGS and promote synergy among Near-Term Pathways research activities, the program will also include crosscutting communication, outreach, and learning initiatives. At the 2008 Annual Meeting held at MIT, participants discussed plans for a third Flagship Program on food and water, Secure Ecosystem Services for a Nourished World. The program will identify development paths for social and technical systems in addressing critical issues of food and water for a burgeoning world population over the next five to 15 years.

Carbon Capture and Sequestration Technologies Program

The field of carbon capture and sequestration is attracting much interest due to increasing concerns about global climate change. LFEE's continuing work on carbon sequestration technologies focuses on three areas: assessment, education/outreach, and basic research. Howard Herzog leads this effort. Some key research thrusts include:

- An integrative assessment of carbon sequestration technologies in collaboration with Professor Henry Jacoby (MIT Sloan School of Management) and the Joint Program on the Science and Technology of Global Change. The focus of the current project in this area is investigating potential penetration rates of sequestration technologies.
- The Carbon Sequestration Initiative, an industrial consortium on carbon management. The 17 members are Alstom Power, American Electric Power, American Petroleum Institute, Aramco Services, Chevron, ConocoPhillips, Electricité de France, EPRI, ExxonMobil, Ford Motor Company, General Motors, Marathon Oil, Peabody Energy, Schlumberger, Shell, Southern Company, and Vattenfall.
- An investigation of social and political factors that will affect the future of carbon capture and sequestration technologies. These factors include siting, permitting, regulatory, and environmental justice, among others. The investigation includes an effort to develop a carbon sequestration information system (using a Geographic Information System as a platform), and a survey to determine the attitudes toward global warming and climate change mitigation technologies, the level of public understanding of global warming and the carbon cycle, and public awareness of carbon dioxide capture and storage (or carbon sequestration). Over 1,200 people, representing a general population sample of the US, responded.
- An economic analysis of the concept of "capture-ready" power plants

In addition, the program has been involved in many national and international efforts related to carbon capture and sequestration. For example, Howard Herzog has been designated as one of the two US Technical Group members for the Carbon Sequestration Leadership Forum, a ministerial-level agreement between about 20 countries to promote research into carbon sequestration technologies.

Funding for the program comes from a diverse number of sources including the DOE, private industry, and NGOs. Additional information can be found on the program web site at http://sequestration.mit.edu/.

Analysis Group for Regional Energy Alternatives

LFEE research in the area of strategic planning for energy infrastructures and environmental performance is centered in the Analysis Group for Regional Energy Alternatives (AGREA), led by Stephen Connors. The scenario-based multi-attribute tradeoff-analysis approach, developed in the 1980s by the DOE's National Renewal Energy Laboratory researchers, is the primary tool used by AGREA. Recent and ongoing projects include the AGS China Energy Technology Program, the Mexico City Air Quality Integrated Assessment, Avoided Emissions from Solar and Wind Power in the US, and Combined Emissions Reduction and Energy Security Strategies for Scandinavia, England (CMI Energy Security Initiative), and Portugal (MIT-Portugal Program). Through the LFEE and AGREA, Mr. Connors also coordinates the sustainable energy activities of the AGS and the MIT-Portugal Program Sustainable Energy Systems Focus Area.

In addition to the projects and programs listed above, Mr. Connors co-supervises numerous independent graduate and undergraduate students looking at the fuel consumption and emissions impacts that are worsening traffic congestion; the widespread deployment of distributed generation technologies; challenges to electrification in Africa and other developing regions; and real options applications to energy investments involving climate change, economic growth, and energy security. Details are available at http://web.mit.edu/agrea/.

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 some 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% of the total energy and more than two thirds of the electricity. The 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.

Four of the five faculty members in the BTP have had strong input to LFEE's or MITEI's energy research and teaching: Professors Marilyne Andersen, John Fernandez, Leon Glicksman, and Les Norford, all of the Department of Architecture. Professor Andrew Scott of the Architecture faculty is also a member of our group and is active in many of our projects. Many of the activities involve substantial joint efforts with faculty members

and students in EECS and ME as well as the Harvard School of Public Health, the city of Cambridge (UK), Chalmers, ETH, and Tsinghua University (China). Typically there are 15 to 20 graduate students carrying out building technology research at any given time. Some students receive degrees in the Department of Architecture, 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; and the application of option theory; and working with the MITEI Campus Energy Management and Education task forces.

Center for Advanced Nuclear Energy Systems

LFEE administered two research projects in the Center for Advanced Nuclear Energy Systems (CANES). Dr. Pavel Hejzlar finished a three-year project investigating fundamental thermal-hydraulic phenomena for advanced gas-cooled reactor applications. Professor Jacopo Buongiorno is studying water-based nanofluids for nuclear systems applications. Both projects are sponsored by Battelle Energy Alliance, LLC. In addition, Professor Mujid S. Kazimi is engaged in a comparison of quantification methods of proliferation resistance of the nuclear fuel cycles.

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 CANES extensive research and outreach activities is at http://web.mit.edu/canes/.

Sloan Automotive Laboratory

A significant amount of LFEE's and MITEE's research volume supports work at the Sloan Automoative Laboratory (SAL). Many of the lab's projects involve quantitative and cross-disciplinary study of complex energy and environmental systems. SAL is directed by Professor John Heywood (ME), with participation from Professor Wai Cheng, Professor James Keck, Dr. Tian Tian, Dr.Victor Wong, and Professor William Green. It continues to pursue promising research to improve engine performance, efficiency, and fuel utilization in internal combustion engines and reduce adverse emissions.

Focusing on new engine and fuel technologies, the Engine and Fuels Research Consortium explores critical fuel/air mixture preparation and emission formation mechanisms in gasoline and diesel engines and in developing engine/fuels concepts. It is funded by automotive and petroleum companies and DOE. Complementing the engine and fuels studies, the Consortium on Lubrication in Internal Combustion Engines involves major engine component and lubricant manufacturers in addressing issues in oil consumption and engine friction reduction. Members in these consortia also sponsor separate research projects on topics of specific interest to the individual sponsors related to engines and fuels. A new consortium with 10 members, focused on developing low ash-producing lubricants to enable significantly improved diesel emission control, is now underway with strong support from the diesel engine industry.

SAL researchers are also involved in multidisciplinary studies assessing new vehicle and propulsion system technologies for future road transportation use. A major study, "Before a Transition to Hydrogen Transportation," is examining 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.

An example of the group's efforts to develop new technology is a downsized gasoline engine concept with fuel economy levels close to today's hybrid engines at much lower cost, which uses ethanol to enable knock-free boosted engine operation. This concept is being developed by Dr. Leslie Bromberg, Dr. Daniel Cohn, and Professor John Heywood.

Center for 21st Century Energy

Codirected by professors Ahmed Ghoniem and John Heywood, the Center for 21st Century Energy, part of the Department of Mechanical Engineering, is affiliated with LFEE and MITEI. The center is encouraging scholars to undertake research in new and mainstream energy technologies and contribute to the broad-based, multidisciplinary assessments and analyses undertaken at LFEE. According to Professor Heywood, "There needs to be a steady stream of people who get involved, especially new people who bring different engineering expertise to these multidisciplinary activities."

Center for Energy and Environmental Policy Research

The Center for Energy and Environmental Policy Research (CEEPR) is an activity jointly sponsored at MIT by LFEE, the Department of Economics, and the MIT Sloan School of Management. CEEPR funds policy-related research in energy and environmental economics. The center receives financial support from corporate sponsors and government agencies such as the US Environmental Protection Agency and the National Oceanic and Atmospheric Administration.

CEEPR research, administered through LFEE, is focused on evaluating the functioning and performance of markets created for environmental services and for electricity and associated network services. Past environmental research has been concerned with emissions trading with particular attention to the US SO_2 Allowance Trading Program and the Northeastern NO_x Budget Program. Recent work includes analysis of the market for carbon created under the European Emissions Trading System. The electricity research is concerned with restructuring decisions with respect to asset ownership, transmission access, and customer choice. CEEPR is also involved in evaluating the future of nuclear and coal energy and in the development of markets for oil and natural gas and renewables. Research includes analysis of financing large scale investments as well as the price dynamics and risk in these markets.

Joint Program on the Science and Policy of Global Change

This program, codirected by Professor Jacoby (MIT Sloan School of Management) and Professor Ronald Prinn (Department of Earth, Atmospheric, and Planetary Sciences), draws on MIT's traditional strengths in science and economics to conduct the serious interdisciplinary work needed to provide a basis for global climate policy. Currently administered through LFEE, the now 15-year-old joint program is one of the world's

leading centers for the integrated assessment of climate change. An MIT Integrated Global Systems Model developed by program researchers provides a facility for research on the climate issue and assessment of policy proposals. An interdisciplinary team of faculty, professional staff, and graduate students carries out the work, and it produces a continuing flow of reports, articles, student theses, and professional and public presentations on the science and policy of global warming. Five US government agencies, 23 corporate sponsors in North America, Europe, and Japan, and one foundation support the work.

Education

LFEE administers the Martin Family Society of Fellows for Sustainability, which inducted 20 new members in spring 2008. On May 1, MIT recognized the tenth anniversary of the Martin Society of Fellows with a day-long series of events to honor Martin family members and the global impact of their generosity to MIT. More than 200 doctoral students have been supported by the Martin Society since its formation in 1997.

Ernest J. Moniz
Cecil and Ida Green Professor of Physics and Engineering Systems
Director, MIT Energy Initiative

More information about the MIT Energy Initiative can be found at http://web.mit.edu/mitei/.