MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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October 21, 2015

Dear members of the MIT community,

I write to share a plan of action for redoubling MIT's efforts to confront the urgent challenge of climate change. This five-year plan represents the shared perspective of MIT's senior officers, informed by extensive discussion, reflection and input from across the MIT community.

We build on last year's **Campus Conversation on Climate Change** and draw insight from the proposals of its organizing committee. I am grateful to Professor Roman Stocker and his committee for helping our community explore this complex and potentially divisive topic with civility, candor and mutual respect, and for producing a thought-provoking report. I also thank the hundreds of faculty, students, staff and alumni who offered detailed comments on the committee's report over the summer. Through this extended exploration, we all learned a great deal—and we saw the MIT community at its problem-solving best.

The Campus Conversation, in turn, emerged in response to efforts of the student-led group, **Fossil Free MIT**, to galvanize systemic action on climate change. The advocacy of these students helped to inspire the plan we issue today; it would not have taken shape as it has without their willingness to work with us toward the shared goal of meaningful climate action. I hope they will join us in this great work.

I am also extremely grateful to the **Conversation Leadership** for the stewardship of this process: Vice President for Research Maria Zuber, Provost Martin Schmidt, Environmental Solutions Initiative Founding Director Susan Solomon and MIT Energy Initiative Director Robert Armstrong. In particular, we are indebted to Maria for the brilliant leadership, broad consultation and consensus building that produced today's far-reaching plan. We will also rely on her for the oversight and ongoing coordination of our research, outreach and convening efforts, to ensure our plan of action succeeds.

Finally, I thank every one of you who participated. I ask you to stay involved. The people of MIT are already hard at work on many aspects of climate change; today's plan unites, extends and accelerates these vital efforts, with fresh energy, urgency and vision.

There is room and reason for each of us to be part of the solution. I urge everyone to join us in rising to this historic challenge.

Sincerely,

L. Rafael Reif

A Plan for Action on Climate Change

October 21, 2015

A joint statement

President L. Rafael Reif
Provost Martin Schmidt, SM '83, PhD '88
Vice President for Research Maria Zuber
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A Plan for Action on Climate Change

Introduction

In these pages, we outline a plan for the MIT community to address the escalating disruption of our global climate.

The people of MIT have strong opinions. Over the past year, intensive discussions brought to the surface a range of ideas about the most effective ways for MIT to act on climate change, and manifested some sharp disagreements about tactics. Divestment was by far the most polarizing. We choose not to divest.

We believe that divestment—a dramatic public disengagement—is incompatible with the strategy of engagement with industry to solve problems that is at the heart of today's plan. Combatting climate change will require intense collaboration across the research community, industry and government. Divestment would interfere with our ability to collaborate and to convene opposing groups to drive progress, at what may be a historic tipping point. For readers interested solely in our decision on divestment, you will find a fuller explanation in Section IV, on page 15.

But if you skip what's in between, you will have missed what we most want to share: our plan for action. This plan embodies the fundamental agreement across our community that the problem of climate change, the subject of serious work at MIT for decades, demands society's urgent attention; that given our mission, history and capabilities, MIT has a particular responsibility to lead; and that the moment is now.

We begin with five guiding ideas.

- The first is our bedrock confidence in the process of scientific discovery. Just as with the depletion of the ozone layer and the rise of acid rain, so with climate change: Science has provided an early warning system. As a species, we are fortunate that climate science has alerted us to a planetary threat. The danger now is clear and present: an imperative to action.
- Second, we believe that when a complex global problem is intertwined with widely used commercial products and services, it will be impossible to solve without the active participation of industry, contributing its ingenuity and practical experience in delivering solutions at scale. Effective action on climate change will require dramatic advances in technology, especially energy technology. Because of our record of working with industry to achieve energy innovation, MIT has a crucial role to play.
- Third, we understand that technology alone cannot solve this problem. Just as difficult as the technical challenges are the human ones, from public awareness to public acceptance, and from politics to policy. From decades of working with governments around the world on complex societal problems, MIT is well positioned to inform policies that can change the incentives for industry, institutions and individuals, and break the deadlock on climate change.
- Fourth, experts and activists are vital—but so is everyone else. Addressing this global problem will take deep societal change. That means there is a role—and a personal responsibility—for *everyone*: every nation, every sector, every institution, every firm, every individual human being. We aim to help inform and inspire a broad societal movement to find climate solutions. We hope you will find your own opportunity, in our plan or elsewhere, to make a difference.
- Last and most important, we believe that, however daunting this challenge, meaningful progress is possible, and abdication is not an option.

In this document, we start with science, which tells us that the risks of climate change are grave. We frame our thinking in terms of MIT's mission and its history of engagement with industry and government, and we outline the Institute's record as a leader in climate science and energy innovation. Framing an important role for MIT in convening academic, industry and government, we then describe our plan for action over the next five years—a set of steps that MIT is pursuing immediately, or will seek funding to support, in order to enhance scientific understanding, accelerate progress on technology and design solutions, educate environmental innovators, share what we know with policy makers and the public, and use our community as a testing ground for change.

As we note above, this plan responds to a petition that we use our investment practices as a form of climate action. We choose to engage deeply and actively with partners in industry; therefore, we choose decisively *not to disengage*. Given its intent to stigmatize, divestment is contrary to the strategy of working with industry that is at the core of MIT's culture of real-world problem solving. Transforming society, as the moment demands, requires transforming our energy system. To move the great stone of the status quo, for MIT direct engagement will be an indispensable lever.

I. What is the problem, and what is our stand?

The science: humanity's early warning system

The Earth's climate is changing, and the preponderance of present-day change is associated with human activity, specifically the emission of CO_2 and other greenhouse gases. Our planet is currently about 0.8°C warmer than it was in the pre-industrial age. The amount of CO_2 in the atmosphere now is greater than at any point in the last 800,000 years, according to polar ice core data—and the concentration continues to rise. For these three statements, the evidence is overwhelming.[1]

Because CO_2 persists in the atmosphere for a very long time,[2] and because the climate system responds relatively slowly, past, current and future emissions will, cumulatively, result in climate changes that will last more than a thousand years; this process is under way now.[3] The warming climate will produce rising sea levels; coastal flooding; droughts and changes in precipitation intensity and distribution; ocean acidification; loss of sea ice; increased wildfires; and impacts on food supply and on animal and plant populations.[4] The world is already beginning to suffer these effects.[5]

The current problem, compounded

These facts are especially troubling because—driven by rising population and rising expectations for living standards around the world—between 2015 and 2050, primary energy use worldwide is projected

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[1] Intergovernmental Panel on Climate Change. Climate Change 2013: The Physical Science Basis. Working Group 1 Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. http://www.climatechange2013.org/

[2] David Archer, Michael Eby, Victor Brovkin, Andy Ridgwell, Long Cao, Uwe Mikolajewicz, et al. Atmospheric lifetime of fossil fuel carbon dioxide, *Annual Review of Earth and Planetary Sciences* 2009 37:117–34. First published online as a Review in Advance on January 26. doi: 10.1146/annurev.earth.031208.100206

[3] Susan Solomon, Gian-Kaspar Plattner, Reto Knutti, and Pierre Friedlingstein. Irreversible climate change due to carbon dioxide emissions. *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* 2009 106(6):1704–1709, doi: 10.1073/pnas.0812721106

[4] Mario Molina, James McCarthy, Diana Wall, Richard Alley, Kim Cobb, et al. What We Know: The Reality, Risks, and Response to Climate Change. American Association for the Advancement of Science (AAAS), 2013. http://whatweknow.aaas.org/wp-content/uploads/2014/07/whatweknow_website.pdf

[5] US Global Change Research Program. National Climate Assessment Report, 2014. http://nca2014.globalchange.gov

to increase by 60%.[6] This growth in energy demand will occur mainly in developing countries and in rapidly growing cities;[7] until humanity devises cheap, scalable, clean energy alternatives, these energy needs will be met largely with cheap, abundant, carbon-intensive coal and other fossil fuels. This will drive further global warming, which could in turn lead to unplanned migrations, increased competition for food and water, and conflict.

The risk

Humanity's current carbon-intensive path imposes risks on future generations, including the risk of catastrophic outcomes. The evidence is compelling that a warming of about 2°C (3.6°F) above pre-industrial levels marks a threshold; after that point, the resulting damage to societies and natural systems around the world becomes increasingly grave. Protecting against this risk is known as "the 2°C challenge."

As individuals, we routinely buy insurance to protect ourselves and our families against the risk of illness and accidents—events we hope will not occur but whose consequences would be devastating. As a society, in deciding how to respond to climate change, the central concept should be reducing risk. The need for action is clear, because the consequences of inaction could be catastrophic.

We now know that to avoid the 2°C threshold in the long-term, human-driven emissions must decrease greatly by 2050 and must eventually reach zero. Given the scale of the risks, the world needs an aggressive but pragmatic transition plan to achieve a zero-carbon global energy system.

To succeed, this plan must address the distinct situations of the developed nations, which have historically produced the majority of carbon emissions and are best positioned to bear the costs of reducing them now, and the developing nations, whose people seek higher living standards (currently carbon-intensive), but who have few or no resources to bear the costs of an energy transition. Many such nations are most at risk from the impacts of climate change, and indeed are already feeling their brunt.[8]

MIT: Mission and History

We approach the challenge of climate change from the perspective of MIT's mission of service to humanity and our distinctive history of engagement with industry and government.

A mission of service to the nation and the world

MIT's mission statement charges us to advance knowledge, educate students and bring knowledge to bear on the world's great challenges, for the betterment of humankind.

As the work of our faculty has helped reveal, climate change ranks among the most serious of those challenges. What's more, it is tangled with others that likewise already command our attention at MIT. Environmental degradation. Disrupted ocean ecosystems and polluted waterways. Extreme weather. Food and fresh-water scarcity. Infectious disease. The rise of megacities and an unprecedented increase in global urban population. Poverty and displaced people.

Making progress against climate change and its attendant problems requires bringing to bear the knowledge of many fields of science and engineering, as well as political science, economics, cultural

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[6] MIT Joint Program on the Science and Policy of Global Change. 2014 Energy and Climate Outlook. Massachusetts Institute of Technology. http://globalchange.mit.edu/files/2014%20Energy%20%26%20Climate%20Outlook.pdf

[7] International Energy Agency. World Energy Outlook 2014. http://www.worldenergyoutlook.org/publications/weo-2014/

[8] World Bank. World Development Report, 2010. Washington DC: 2010. http://siteresources.worldbank.org/INTWDR2010/Resources/5287678-1226014527953/WDR10-Full-Text.pdf

studies, management, entrepreneurship, architecture and urban design. It also demands an aptitude for hands-on problem solving, the power to convene leaders from many disciplines and sectors, a willingness to engage with diverse communities in designing the future—and a humane grasp of our moral responsibility to the Earth and its creatures, including our children and our fellow, and future, human beings.

Drawing on MIT's particular strengths, our community is equipped to make important new contributions to addressing the climate problem—and our mission tells us that we must.

A history of engagement with industry

The Institute was founded in the mid-19th century to accelerate America's Industrial Revolution through education and research—and it did, producing many of the ideas, individuals and industries that established the United States as an industrial powerhouse and that helped drive wave after wave of economic growth and rising living standards. From MIT's inception, the success of its model has depended on close working relationships with industry, structured to guard our intellectual independence.

Since the 1920s, when MIT began collaborative projects with Standard Oil, fossil fuel companies have consistently been among our most productive research partners. MIT helped pioneer the field of chemical engineering; arguably no industry has benefited more directly from that field's principles and discoveries, nor used them to create more societally significant products, than the oil industry. In the 1930s, two MIT professors were instrumental in the development of fluid bed catalytic cracking, the standard technology used even now to produce gasoline. In the decades since, generations of MIT graduates have pursued careers in the fossil fuel industry, in the US and abroad.

Through our faculty, students and alumni, we also engage with companies from across the entire energy value chain by supporting the development of low- and zero-carbon technologies, guiding the design and regulation of new power systems capable of supporting much greater levels of renewable resources, and helping MIT entrepreneurs bring new clean energy solutions to the market faster.

MIT also regularly partners with industry to pursue research in fields such as building energy efficiency, industrial energy efficiency, urban transportation systems, aircraft efficiency, carbon capture and sequestration, economic policy and more.

The depth and range of our industry engagement, combined with our extensive work with energy and environmental policy makers around the world, position us to accelerate climate progress.

A history of engagement with government

Since our founding and particularly since World War II, MIT has worked closely with the US government on projects of consequence, from radar and landing on the Moon to computing and the defense research of Lincoln Lab. We also serve the government as a trusted independent voice on complex policy, from the best path for accelerating life science research, to the future of online education, advanced manufacturing and energy technologies. We aim to build on those decades of trust and collaboration, because effective US action on climate change will depend on action by the federal government.

We can also build on our extensive record of working with other national governments on critical environmental and resource issues, from close, longstanding collaborations with Singapore and Abu Dhabi, to ongoing projects with India and China, to recent work on equitable ways to allocate water among Ethiopia, Egypt and Sudan.

II. What has MIT done so far?

As we accelerate our efforts in climate science and energy innovation, MIT researchers and inventors already stand at the frontier.

Climate research, communication and policy

Since even before 1979, when Professor Jule Charney led a National Academy of Sciences report[9] now regarded as that era's most important "early warning" document on the likelihood and risks of climate change, MIT has built a record of influential climate research and of advancing the communication and policy of climate science.

MIT researchers have also helped build a comprehensive understanding of the fundamental physics and dynamics of the Earth's climate and made essential discoveries, including the possibility of "multiple equilibria" in the climate system (implying the risk that the climate could shift rapidly from one state to another), the nature of climate catastrophes in Earth's history, and the likely changes in frequency and intensity of hurricanes in a changing climate. MIT's Joint Program on the Science and Policy of Global Change and the Center for Global Change Science have done groundbreaking work that demonstrates how climate science, policy and economics interact. And MIT faculty also played an important role in developing the principle of cap and trade policy—originally for sulfur dioxide emissions, now applied to greenhouse gases—which has been adopted in Europe and is being actively considered in China.[10,11]

Energy research, education and policy

Launched in 2006, the MIT Energy Initiative (MITEI) is one of the largest and most successful academic energy programs in the world. About 65% of MITEI research funding comes from industry, 20% from the federal government and 15% from philanthropy; funding commitments to date amount to $600M. More than two-thirds of MITEI's broad portfolio focuses on renewable and energy efficiency technologies and policy; the majority of these projects are sponsored by industry.

MITEI has fostered a thriving research community at MIT, engaging 30% of MIT faculty members, from 23 departments; thousands of graduate students, including more than 350 graduate fellows; and more than 200 undergraduates, some enrolled in MIT's energy minor. Since the start of MITEI in 2006, MIT has also spun out more than 40 start-ups in energy fields.

MITEI researchers have made game-changing advances to enable a low-carbon future across the technology spectrum, ranging from low-cost solar cells made from quantum dots printed on paper and plastic; to molten-metal grid-scale batteries for storing solar and wind energy that are built to last for decades; to conceptual designs that may one day make fusion power not only possible, but affordable. In 2012, *Smithsonian* magazine chose a MITEI innovation—nanoporous graphene membranes as a low-energy means of desalination—as one of that year's top five surprising scientific milestones.

To help the developing world devise sustainable approaches to meeting soaring energy needs, MITEI has also set up many collaborative international research partnerships, most recently in India and Africa through the Tata Center for Technology & Design, and in China through the China Energy &

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[9] Jule Charney, Akio Arakawa, D. James Baker, Bert Bolin, Robert E. Dickinson, Richard M. Goody et al. Carbon Dioxide and Climate: A Scientific Assessment. Report of an Ad Hoc Study Group on Carbon Dioxide and Climate. Woods Hole, Massachusetts, July 23–27, 1979, to the Climate Research Board, Assembly of Mathematical and Physical Sciences, National Research Council, National Academy of Sciences. http://www.nap.edu/read/12181/chapter/1

[10] A. Denny Ellerman, Paul L. Joskow, Richard Schmalensee, Juan-Pablo Montero, and Elizabeth M. Bailey. *Markets for Clean Air: The U.S. Acid Rain Program*. Cambridge: Cambridge University Press, 2000.

[11] A. Denny Ellerman and Barbara K. Buchner. The European Union Emissions Trading Scheme: Origins, Allocation, and Early Results. *Review of Environmental Economics and Policy* 2007 1(1):66–87.

Climate Project. Over the past six years, and especially the past six months, MITEI has also led high-level discussions with the Indian and Chinese governments to explore strategies that would expand energy access for their people while reducing environmental impacts. Based on the Tata Center's success, MITEI is rapidly expanding its effort in Africa, in concert with industry partners and development agencies including the UN and the World Bank.

MITEI has also directly influenced national legislation and Department of Energy policy through its "Future of" reports on key aspects of the global energy system, including nuclear power; carbon capture and sequestration for coal; natural gas; solar energy; and the grid. And in keeping with the Pentagon assessment that climate change presents "an urgent and growing threat to our national security,"[12] MIT's Lincoln Laboratory technical staff has engaged in work on energy security and the impacts of climate change, as well as satellite remote sensing technologies relevant to global monitoring.

Beyond MITEI

MIT's contributions extend beyond MITEI's research portfolio to include advances in nuclear energy; commercial and residential building energy efficiency; industrial energy efficiency; transportation and mobility; and economic policy analysis and design. To touch just one category, in 1939, MIT pioneered the design and engineering of solar-powered houses, including the first occupied solar-powered house in the US. Today, with the growing emphasis on net zero energy building design, the Building Technology Program in the Department of Architecture is a world leader in renewable energy solutions for the built environment and is deeply engaged with many industry partners. Similarly, the Department of Nuclear Science and Engineering is internationally known for its leadership in the technology and safety of nuclear energy systems.

III. How will MIT intensify its impact?

The challenge before us is formidable. We must understand the complex working of the climate system and its response to natural and human influences. We must produce more energy to meet the needs of a growing population while at the same time slashing emissions in absolute terms. We must be mindful of *global* context; our ability to find solutions that work for the developing world—facing rapid urbanization, high demand growth and low incomes—is crucial. And we must be alert to the fact that even as the world as a whole will benefit from the transition to a low- or zero-carbon energy system, not everyone will benefit equally, and the short-term effects for some may be painful.

That is an immensely difficult problem, a scientific, technological, systems and societal problem of the highest order.

Key global players in three sectors—academia, industry and government—will need to work together through three overlapping stages of progress. The first step is to imagine the future as informed by research: e.g., What is the optimal mix of energy sources in 15, 25 and 35 years, in order to meet emissions targets and eventually reach a zero-carbon global energy system? And how can societies across the globe best adapt to damaging climate impacts in the meantime? Next, it will be vital to establish the policy and economic incentives to achieve that future. Finally, clear technological goals and aligned incentives will focus and accelerate the research and development required to achieve success. All three phases need to be continuously refreshed: Research and development should continuously inform timelines and targets. The success of this strategy depends on the best efforts of all three sectors.

[12] US Department of Defense. National Security Implications of Climate-Related Risks and a Changing Climate. 23 July 2015. http://archive.defense.gov/pubs/150724-congressional-report-on-national-implications-of-climate-change.pdf?source=govdelivery

Building on MIT's distinctive history of connecting with government and industry—and eagerly joining forces with others who are working this problem from their own positions of strength—we hope MIT can make a significant contribution to designing and jumpstarting this crucial convening work. We intend to begin right away.

Simultaneously, and in collaboration with colleagues around the world, we must advance many aspects of science, technology, design and policy, drawing on insight and creativity from across MIT's five Schools, and from our staff.

Below we detail MIT's plans for direct action. Through broad consultation across the MIT community, we found this set of actions to have consensus support.

Delivering on these plans will involve the coordinated efforts of many groups at MIT, including our Environmental Solutions Initiative (ESI), MITEI, our Office of Sustainability and the many other departments, labs and centers engaged in related work. Maximizing communication and collaboration across this community, increasing outreach beyond our campus—and fostering MIT's climate effort overall—will be a central responsibility for the new director of ESI, Professor John E. Fernández.

Much of the new work can begin immediately. Fully implementing our scaled-up research agenda will require serious new resources, so we enthusiastically seek partners and sponsors. Raising funds for these and other climate-related efforts will be a priority of MIT's upcoming capital campaign.

The work we outline here will unfold over five years; at that point, we will assess our progress, gauge the broader state of play on climate issues and determine how MIT can most effectively continue to drive progress on climate action.

Our objective: to minimize emission of carbon dioxide, methane and other global warming agents into the atmosphere, and to devise pathways for adaptation to climate change, through the active involvement of the MIT community, proactively engaged with industry, government, academia, foundations, philanthropists and the public.

To reach that objective, we will:

- **A** Improve our understanding of climate change and advance novel, targeted mitigation and adaptation solutions
- **B** Accelerate progress towards low- and zero-carbon energy technologies
- **C** Educate a new generation of climate, energy and environmental innovators
- **D** Share what we know, and learn from others around the world
- **E** Use our community as a test bed for change

A. Improve our understanding of climate change and advance novel, targeted mitigation and adaptation solutions

MIT's Environmental Solutions Initiative was founded to catalyze integrated research across disciplines, focused on dismantling obstacles to progress in reducing the risks of climate change. Through its first round of seed grants, ESI is supporting nine cross-disciplinary projects whose teams would not otherwise have been able to collaborate.

MIT is providing $5 million to seed new ESI research and will seek outside support for new work that faculty define as most promising. Future topics might include research to:

- improve the predictive power of climate models
- advance strategies for adapting to the impacts of climate change, from urban planning and infrastructure transitions to agriculture
- collect and interpret atmospheric gases to track air quality in major cities
- minimize damaging environmental impacts of metals and minerals
- develop strategies for mitigating potentially very large greenhouse gas emissions from tropical peat lands
- improve management of water resources in various environmental settings.

In its first year, ESI emphasized foundational research. Beginning now, with funding from MIT and with the guidance of ESI Director Fernández, ESI will use rounds of seed grants to expand and accelerate its research, build connections between research groups and increase engagement with the MIT community.

On this foundation, ESI will fast-track a portfolio of projects focused on providing novel solutions for mitigating and adapting to climate change. ESI is poised to repeat the success of MITEI in building a comprehensive research program, anchored in science, engineering, management, design and planning, and a broad understanding of society, and promoting actions on the MIT campus, in partnership with the cities of Cambridge and Boston, and reaching far beyond.

The Abdul Latif Jameel World Water and Food Security Lab

Founded in 2014 to coordinate MIT's research in water and food, the Abdul Latif Jameel World Water and Food Security Lab (J-WAFS), led by Professor John Lienhard, seeks environmentally benign, energy-efficient and scalable solutions for water and food systems across a range of regional, social and economic contexts by incubating technologies and fostering innovative regional collaborations. As part of its broad mission, J-WAFS seeks pathways for supplying fresh water and food for the world's growing population as the pressures of climate change increase.

Responsibility for coordinating J-WAFS efforts with the rest of ESI will fall to ESI Director Fernández.

B. Accelerate progress towards low- and zero-carbon energy technologies

MIT and the students we educate represent a powerhouse of research and innovation; these areas of strength constitute far and away the greatest opportunity for MIT to make a difference on climate change.

To accelerate progress towards low- and zero-carbon energy technologies, we will launch eight low-carbon energy centers, advance research on transforming major energy systems and conduct an ambitious study on how best to overcome the challenges of staying within the 2°C limit.

Eight New Low-Carbon Energy Centers: Five now and more to follow

Building on the extensive work of our faculty and MITEI's corporate members, MITEI will convene a diverse group of companies to fund work on fundamental challenges that stand in the way of breakthroughs. The mechanism: a set of eight focused Low-Carbon Energy Centers. Each center we envision—five ready now, with more to follow shortly—will seek approximately $8 million in funding every year, in addition to MITEI's current base of support. Over five years, this will enable more than $300 million in new energy research at MIT.

We intend the centers to stimulate broad new industry participation, including from smaller firms, and firms from the developing world unfamiliar with academic collaboration. To bring these fresh perspectives to the table—in effect, to democratize access to our innovation ecosystem—we are significantly lowering funding barriers for participating. The Low-Carbon Energy Centers will serve as a base for companies that want to engage in a portfolio of research projects, but that lack money to support more than one or two at a time. The centers will be convened and coordinated by MITEI's director, Professor Robert Armstrong.

The Solar Center
As the largest source of renewable energy, solar power will almost surely be critical to a sustainable future. This spring, MITEI released its latest study, "The Future of Solar Energy," a comprehensive, multidisciplinary assessment of current technology, R&D and policy. It concludes with a description of what needs to be done in these areas to enable solar power to play a significant role in global energy systems by midcentury; the center's research agenda starts there. The Solar Center will also explore solar thermal technologies, from fundamental science in thermoelectrics to new system concepts for concentrated solar power.

The Center for Energy Storage
Energy storage is of interest for uses ranging from consumer electronics and vehicles to residential, commercial and utility equipment, and on time scales from milliseconds to months. A critical problem is large-scale energy storage, which is indispensable for the successful incorporation of solar and wind generation into the power grid. Storage for transport is also a key challenge. The Center for Energy Storage will tackle the fundamental challenges that limit the development of transformative storage technologies. Areas of focus will include electrochemical storage (batteries, fuel cells, flow batteries and supercapacitors); solar-to-fuels (CO_2 reduction and water splitting); and thermal storage (thermo-chemical, thermogalvanic cells). The center will also focus on mechanical storage like pumped hydro and flywheels.

The Center for Materials for Energy and Extreme Environments
This center will deliver basic-science-guided innovations involving revolutionary materials and surfaces used in energy technologies to enable predictable long lifetimes in harsh environments over decades. Every year, uncontrolled material loss, deposition and interior damage through corrosion, fouling, fracture and radiation cost more than 4% of US GNP and enlarge the anthropogenic carbon footprint by limiting the efficiency and durability of nuclear, wind, solar and fossil energy, as well as of fuel cells and thermo/electrochemical ways of making new fuels. The MIT team will develop new materials, processes, diagnostics and software to improve economics and efficiency, and to reduce carbon emissions and other environmental impacts.

The Center for Carbon Capture, Use and Sequestration
Making the transition to a clean energy economy will, at least in the near term, involve the use of carbon-intensive coal, particularly in the developing world. Carbon capture, use and storage (CCUS) technologies can contribute as a bridging strategy to reduce the emission of carbon to the atmosphere. Bringing affordable CCUS to scale is a difficult but solvable problem that requires expertise ranging from novel chemistry and biology for capture, to subsurface science and engineering at field scale for sequestration. This center will pursue cross-disciplinary research in engineering, science and policy, and build strong partnerships across academia, industry and government.

The Nuclear Energy Center
Nuclear energy is already making a major contribution to climate mitigation efforts worldwide, and today's nuclear plants are much safer than the first generation of commercial fission reactors, built more than 40 years ago. However, if nuclear power is to help drive the transition to an affordable, reliable, low-carbon global energy system, it needs to be made safer still, as well as less expensive, more secure against the threats of nuclear proliferation and terrorism, better

suited to the needs of developing economies, and better able to provide low-carbon energy inputs for a broad range of applications beyond conventional baseload electricity generation. The MIT team will help to invent the future of fission energy by developing new kinds of nuclear power plant systems; new materials, construction methods and technologies to make nuclear energy safer, more affordable and easier to deploy; and new strategies to enable a zero-carbon grid to meet variable electricity demand while fully utilizing nuclear, wind and solar generating capacity to minimize total costs.

Three additional Low-Carbon Energy Centers in subsequent years
Over the next year or so, we plan to set up three additional centers, focused on **nuclear fusion**, **energy bioscience** and the **electrical grid**. Like the five centers described above, each builds on considerable strength at MIT, and each will play a crucial role in achieving a low-carbon future.

New research to transform major energy systems

Through the combined efforts of MITEI and ESI, we will also seek funds to accelerate work in the following key areas:

The Utility of the Future
Our energy future depends on reimagining the architecture, size, reliability, security, adaptability and resilience of our current power system—the "grid" and all it entails. Our "Utility of the Future" study—an ongoing analysis that involves MIT researchers and a consortium of industrial and other stakeholders—is addressing emerging issues in the electric power sector, including the economic, regulatory and technological impacts of the ongoing evolution of the power system worldwide.

Mobility of the Future
Of all the primary energy use sectors—electricity, transportation, industry and buildings—transportation is the toughest to decarbonize because of the challenge of economically replacing the energy density of fossil fuels. Nevertheless, in the decades ahead, higher efficiency vehicles, advanced engines, new fuels and new mobility modes will offer substantial opportunities to reduce greenhouse gas emission and fossil fuel consumption. A central question is which combination of vehicles and fuels will be most appealing to consumers under various greenhouse gas reduction scenarios.

Our objective is to provide an analytic framework to assess the effect of different combinations of vehicles and fuels on consumer satisfaction, cost and environmental impact, especially greenhouse gas emissions. In addition to the familiar bus/jitney or commuter rail, we will analyze the implications of more radical changes including widespread car sharing, autonomous vehicles and remote synchronous vehicle traffic control systems. This assessment will cover regions of high-penetration, low-growth of passenger vehicles (North America) and regions of low-penetration, high-growth (China).

Flight of the Future
In terms of its effect on climate change, air transportation is a source of particular concern for three reasons: This sector will likely maintain its reliance on liquid fuels because of their high energy density; aviation CO_2 emissions are forecast to double or triple by 2050, making it one of the fastest growing sources of CO_2; and since emissions from aviation occur at high altitude, they result in greater climate impact than the equivalent from ground sources. MIT is working to advance scientific understanding of how aviation's high altitude emissions affect the atmosphere, including changes to atmospheric chemistry and cirrus cloud cover. Through MIT's close working relationships with regulators in the US and worldwide, our work informs new environmental standards for aviation.

An additional challenge is that because aircraft have an operational life of around 30 years and they are expensive to replace (more than a trillion dollars of commercial aircraft are in service today), they are rarely retired early. This means that even major technological breakthroughs would take decades to affect emissions. While we pursue technological advances in aircraft and gas turbine design, MIT is also assessing the potential of biofuels and efficient operational procedures to reduce aviation emissions in the short term.

City of the Future

Cities are both major contributors to climate change and promising centers for solutions. More than half the world's population now resides in cities, consuming the majority of materials extracted from the lithosphere and 67% to 77% of energy worldwide. Cities also account for 75% of global carbon emissions.

From the global south to poor urban neighborhoods throughout the developed world, many cities struggle to provide their residents with the minimum of life-sustaining resources, even without the future stresses we can anticipate from climate change. Many cities also face problems—water shortages, heat related deaths and vulnerability to sea level rise—that will be exacerbated by global warming.

Yet as centers of innovation, cities serve as ideal test beds for technologies and policies aimed at delivering services with lower carbon emissions, such as building-integrated photovoltaics and solar thermal, smart grids, combined heat and power urban districts, bus rapid transit and other sustainable transportation solutions. Other urban challenges, like acute pollution from coal-fired power plants and unhealthy air from gas combustion engines in city centers, might be eased by the same technologies invented primarily to reduce carbon emissions.

ESI will work with MIT's multi-disciplinary community of researchers in all five Schools to advance work in low-carbon logistics and transportation systems, urban weather and the heat island effect, urban energy modeling, sustainable urban metabolism, smart and digitally enabled cities, city environmental policy and energy management, and other domains.

A new study: The 2°C Challenge: Accelerating the Transition to a Zero-Carbon Future

Building on MITEI's influential "Future of" reports, MIT is commissioning an accelerated study to produce a roadmap of the coordinated scientific, technological and policy approaches it will take to best protect the world from exceeding the "guardrail" temperature rise of 2°C—in effect, a "Future of Life As We Know It" report, which we will share aggressively with government leaders at every level. This work will be led by Professors Ronald Prinn, Susan Solomon and Robert Armstrong, and Dr. John Reilly.

Applying its strengths in technology and the natural and social sciences, and its history of engaging both the private and public sectors, MIT will assess pragmatic paths that would increase the chances of the world meeting the 2°C challenge. MIT is in a unique position to elucidate the detailed road maps to achieve this challenge, and then, crucially, to move from planning to making substantive contributions toward execution, all within a single institution. Emphasizing both uncertainty and the value of information regarding technologies and costs, climate response, and sustainability of new technologies at large scale, this approach has not been attempted before.

C. Educate a new generation of climate, energy and environmental innovators

Perhaps the most powerful way to trigger new thinking on climate is to educate a new generation of innovators—here on our campus and around the world. In addition to the extensive educational opportunities we currently offer to our students in this area, we will:

Develop an Environment and Sustainability degree option
Meeting the climate challenge will require collaboration among people trained in disparate fields but who share a fluency in climate science; with a new minor in Environment and Sustainability, all MIT undergraduates will have the option of developing this "bilingual" strength. Thanks to the generous support of Derry and Charlene Kabcenell, today we announce that funds are available to develop or adapt a sequence of options for interdisciplinary, problem-centered courses focused on climate change and related environmental crises. Classes will be drawn from all five Schools, underscoring our recognition of the economic, political, cultural and design dimensions of thinking about the environment and sustainability. Together these courses will make possible a new Environment and Sustainability Minor. With the leadership of Professor Susan Solomon, we expect to have this in place by the fall of 2017.

Develop an online Climate Change and Sustainability credential
The impacts of climate change are likely to be felt first and worst in parts of the developing world, where advanced education can be hard to come by. To help people everywhere educate and empower themselves on the subject of global warming, we will develop an *MITx* Climate Change and Sustainability credential, building on Professor Kerry Emanuel's outstanding course on climate change. Via edX, it will be open to unlimited learners around the world. The credential will be available soon; we urge you to sign up! For those who can't wait, the Sloan School already offers a Sustainability Certificate and plans to make it available to the broader MIT community.

Explore broad adoption of principles of "benign and sustainable design"
Engineers, architects and other designers have long considered "environmental externalities" in their work. But to make the practice more rigorous, far-reaching and systematic, it must be built into how and what we teach. We have asked Dean of Engineering Ian Waitz and Dean of Architecture and Planning Hashim Sarkis to explore with their faculty ways to inject principles of "benign and sustainable design" throughout MIT's engineering and design curricula. In addition, the School of Humanities, Arts and Sciences offers courses in anthropology, and through the program in Science, Technology and Society, that contribute to how humans and cultures think about and experience design. These courses will provide models and different points of view on what is considered benign and sustainable. We will also reach out to peer universities to learn from their experience and explore ways to make these principles more universal.

D. Share what we know, and learn from others around the world

MIT often serves as an independent voice in contentious, technically grounded policy debates. In that spirit, and at the urging of the Climate Change Conversation Committee, we will accelerate our efforts to offer the public a trusted source of climate change information, to engage leaders and citizens in the effort for solutions, and to use MIT's expertise in online education to dramatically expand our reach. To those ends, under the coordination of ESI:

We will educate leaders in industry and government through a new suite of short courses and executive seminars—using online learning technologies to reach leaders everywhere and at every level, far from Cambridge or Washington, DC—on the risks of and options for combatting climate change.

We will expand the capacity of MIT's Climate CoLab. This digital community, led by more than 200 experts, has already engaged nearly 50,000 individuals from over 170 countries to crowdsource climate priorities and novel solutions. We will support its expansion as a vital asset.

We will mobilize the strength of our alumni. MIT's 130,000 alumni represent an exceptional untapped resource for driving substantive progress on climate change—and we are certain that our graduates will know better than we do how to make the most of their strength, from their

technical expertise to their professional and community networks. With practical support from MIT's Climate CoLab, today we open a competition to determine the most effective ways for the MIT alumni community to help MIT implement today's plan. We urge you to join in.

We will create a web portal on climate change to supply the public with timely, accurate climate information and offer diverse expert perspectives.

We will pursue solutions through the convening power of "Solve." This October, MIT hosted the inaugural session of "Solve," an effort to convene a wide range of influential thinkers and doers with the power and position to drive progress on a set of great global challenges, including climate change. MIT will convene Solve each year, and in the intervening months will work with participants to sustain the momentum for progress.

E. Use our community as a test bed for change

As we work to pioneer technologies and policies to help society combat climate change, we feel a keen responsibility to improve the sustainability of our campus and to use it as a test bed for faculty, student and staff ideas. Moreover, we will actively share pertinent results of our reduction strategies and related research projects, in case they could be helpful to similar campuses and organizations around the world. We begin with these steps:

We will reduce campus greenhouse gas emissions 32% by 2030.
In its campus operations, MIT will pursue a coordinated suite of carbon-reduction strategies focused on power generation, distribution and demand management. After careful study, we believe this path makes an initial 32% reduction feasible despite projected growth of the campus; we will pursue further reductions if possible. These strategies will include making significant improvements to the cogeneration plant that provides 85% of campus energy; pursuing additional renewable energy options for our remaining power requirements; and renewing our aging utility distribution system. MIT is also committed to the integration of low-carbon design strategies, and ultra-efficient energy technologies within our buildings. We will develop and share a *campus* climate action plan within the year.

We will eliminate the use of fuel oil in campus power generation by 2019.
As a component of our capital renewal plan, natural gas will be the primary fuel source in MIT's Cogeneration Plant. Ultra-low-sulfur diesel will be used only in emergency situations.

We will actively pursue new carbon-cutting strategies across campus.
Capturing the recommendations of the 2015 Sustainability Working Groups, the upcoming Campus Sustainability Report aligns campus operations along a set of sustainability principles, putting MIT on a path to being a state-of-the-art sustainable campus. The report leverages the MIT 2030 Capital Renewal Plan, identifying this major campus transformation as presenting rare openings to invest in efficient building systems, envelopes, metering and new technologies. MIT is committed to an integrated design process that factors sustainability into the design, construction and renovation of all new and existing MIT buildings, including their systems, materials, sites and infrastructure. In the next fifteen years, for example, the majority of building roofs at MIT will be replaced. We will take advantage of this opportunity to evaluate and deploy a range of sustainable roof strategies, from today's solar panels to "green roofs" and beyond. We will also use the renewal process to create "green laboratories."

We will enact "carbon shadow pricing."
A central problem in fighting climate change is that carbon emissions are effectively "free"; neither individuals nor institutions have much direct incentive to cut back. Appropriate pricing of carbon is widely accepted as an essential policy instrument to help mitigate climate disruption.

As we push toward our 32% reduction in carbon emissions, we will experiment with the effects of including in our institutional decision-making an honest accounting of carbon costs. This will require that we design, implement and assess the effectiveness of a carbon "shadow pricing" plan; to start with, it would be intended to influence all future capital renewal projects. We will also study selected aspects of end-user carbon pricing on our campus, to provide data that students and faculty can use to study what policies would best reduce carbon emissions by changing habits and behaviors.

We will deploy an open data platform for campus energy use.
To improve our energy management and to provide faculty, staff and students with a useful resource for research and intelligent decision-making, we will institute a new regime to measure campus energy use and will share our findings through an open data platform.

We will activate our campus as a living lab.
As we renew the campus, we will actively seek opportunities to test carbon efficient technologies and practices, and to offer hands-on education in climate science and sustainable design. This might include a rooftop-testing facility for the kind of solar technologies our faculty and students are busy inventing even now.

IV. The Question of Divestment

This section describes how divestment emerged as an issue on our campus and why we have chosen not to divest.

The student-led group Fossil Free MIT has presented a petition with around 3,400 community signatures, calling on MIT to divest any holdings in a group of 200 fossil fuel companies whose identified reserves, if burned, would send the global climate over the 2°C limit that we highlighted in Section I. Their goal, as we understand it from them, is to use the pressure of an international movement of high-profile institutional divestment to draw attention to the seriousness of the climate threat, and to trigger action against it, by publicly stigmatizing the practices of the fossil fuel industry.

We agree entirely on the seriousness and urgency of the climate threat, and on the need for MIT to play a public leadership role. However, after studying this question, we conclude that divestment is incompatible with the strategy of engagement that forms the heart of today's plan. Serious action to confront climate change demands intense collaboration across the research community, industry and government; divestment would thwart our ability to collaborate and to convene opposing parties and inspire united action.

In our judgment, a symbolic public move to divest is not the most effective way for MIT to drive progress on the climate challenge, and pursuing it would interfere with the two strategies MIT should pursue because of their promise for direct progress: active engagement and bold convening.

As the plan we share today makes clear, we find that the best way for MIT to accelerate action on the climate challenge—in science, in technology, in policy and in the education of our students—is active engagement with organizations of many kinds. Rapid progress will depend on our collaborating with a wide range of industry partners, from the most disruptive local solar start-ups to fossil fuel giants that have mastered the challenges of delivering energy to millions of households.

Furthermore, acceleration will depend on our ability to help industry and government understand each other, on the road to designing sound policy incentives. We also see a unique opportunity for MIT to serve as a convener of widely different voices and sectors—from activists to industry leaders—to help

shift the public dialogue on climate from deadlocked argument to a constructive conversation about solving problems.

Some argue that it would be possible to take a symbolic stance against greenhouse gas emissions by publicly divesting from fossil fuel holdings, while also continuing to work with fossil fuel companies in these many contexts. We disagree.

In our judgment, the deliberate public act of divestment would entangle MIT in a movement whose core tactic is large-scale public shaming. This would retard rather than encourage the open collaboration and ability to hear new ideas that are central to our research relationships, central to our ability to help government and business think creatively together, and central to our ability to convene and inform the thinking of those with opposing views.

Throughout the last two years, the student leaders of Fossil Free MIT have acted with great respect, in a spirit of candor and collaboration. We believe that we should behave the same way toward fossil fuel companies.

We are not naïve about the pernicious role of some segments of the fossil fuel industry in creating the current policy deadlock. We deplore the practice of "disinformation," through which some industry players and related groups have obstructed public understanding of the problem of climate change. We are engaged in candid conversations with industry allies, and we will continue to advocate frankly with them as we all work together for systemic solutions to climate change, including a price on carbon; such a policy shift would change the incentives for us all and make fossil fuel companies, a rich source of technical talent, a central source of progress.

A tipping point

As with the protection of the ozone layer, well-crafted policies can harness the creative forces of industry to serve the common good. We judge that growing awareness of climate change may be generating a tipping point in that policy dynamic now. Witness the fact that in Paris last Friday, October 16, 2015, the CEOs of ten of the world's largest oil and gas companies declared that their "shared ambition is for a 2°C future," and called for "an effective climate change agreement" at next month's 21st session of the UN Conference of Parties to the UN Framework on Climate Change (COP21).

Six of those companies—BP, Eni, Saudi Aramco, Shell, Statoil and Total—are members of MITEI. We believe we have greater power to build on such momentum not by distancing ourselves from fossil fuel companies, but by bringing them closer to us.

We have chosen different tactics than those in the Fossil Free MIT petition. But our ultimate goal is not different. The members of Fossil Free MIT and the Climate Change Conversation Committee, many of whom are personally engaged in advancing leading-edge climate science and renewable energy technologies, stimulated much of the thinking that produced the coordinated commitments in the plan we issue today. Above all, they brought climate change to the top of MIT's *institutional* agenda by urging that MIT assume a role of public leadership.

We step up to that challenge with this plan—and with the tide of new ideas and energy we hope it will unlock across the global community of MIT. We hope everyone in our community—including those who wish we had divested—will work with us to help this vital effort succeed.

V. Conclusion

In 1995, Mario Molina, then a professor at MIT, shared the Nobel Prize in Chemistry for pioneering work he did as a post-doc in the early 1970s that connected chlorofluorocarbons (CFCs), then widely used in applications from aerosol sprays to air conditioning, to depletion of the Earth's protective ozone layer. His research, combined with the work of field scientists who detected a growing ozone hole over the Antarctic, was critical to the passage of the Montreal Protocol, the 1987 United Nations agreement that banned the use of CFCs.

Today, the ozone hole is gradually healing, and the Montreal Protocol stands as the most effective global environmental treaty ever.

This past spring, Dr. Molina, whose many roles include climate advisor to the President of his native Mexico, returned to MIT to deliver an urgent message. Speaking to an overflow crowd of faculty and students, he described the sobering risks associated with climate change. And he called on the MIT community to use its stature, talent and resources to communicate the threat of climate change; to help overcome the kind of doubt, industry resistance and policy deadlock that he encountered during the struggle over ozone; and to help drive rapid progress towards real solutions.

We share Dr. Molina's assessment that climate change and its many interrelated problems present risks too grave to gamble with. To solve this global problem, humanity must reorder the global energy status quo. To make a serious difference, we are eager to engage everyone we can. This is too important. We ask you to join us.