MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY of GLOBAL CHANGE

Global Changes

Summer 2012 | In this Issue

MISSION AND OBJECTIVES

Integrating natural and social science to further the international dialogue toward a global response to climate change

- Discover new interactions between natural and human climate system components
- Objectively assess uncertainty in economic and climate projections
- Critically and quantitatively analyze environmental management and policy proposals
- Improve methods to model, monitor and verify greenhouse gas emissions and climate impacts
- Understand the complex connections among the many forces that will shape our future

IN THIS ISSUE:

Dear Sponsors,

Our discussions at the Sponsors Meeting and Global Change Forum in March provided useful feedback on how we can create greater value for you as a sponsor of the Program. The message we heard loud and clear was your desire for improved communication. Since then, we've been working to implement several of your suggestions. Central to this effort are two new features on our sponsors-only website: Pre-Release Publications and the Discussion Board. The Pre-Release Publications page is our way of providing you with early access to our latest findings—the new research summaries and interviews with researchers attempt to make the key results more accessible. The drafts of publications we provide have been reviewed internally, but the findings should be treated as preliminary. As such, we ask that you do not circulate them outside your organizations without first contacting the authors—in some cases advance publicity and circulation can prejudice journal publication. The Discussion Board provides a new way for you to communicate with researchers in the Program or other sponsors on any element of our research, related news items, or other topics. Of course, you are always welcome to contact us through other means. The advantage of the Discussion Board is that many of these questions, issues and answers will be of interest to other sponsors, and with a record of discussion we can cross reference earlier topics if they are relevant to a new question. The Discussion Board is an experiment and will only be as active as we all make it. Several other projects are still in the works, so watch for new features and please share your ideas with us. In the meantime, the Sponsors Webinars will continue and have proven to be a very effective communication mechanism on high-profile topics.

Along with these improved communication efforts, we continue to pursue our program of policy-relevant research. The following pages provide an update on recent research findings. You will also learn in this newsletter about some changes within our organization, as students and friends leave and others join the Joint Program community. As we announced at the March Sponsors meeting, a key new addition is Veronique Bugnion who will be taking up many of the responsibilities of Loren Cox as he transitions into retirement. We have used this newsletter as an opportunity to introduce her to you. She looks forward to meeting all of you in person. As always, we and Veronique very much welcome your ideas for potential new sponsors of the Program. Your strong words of support for the Program provide the most compelling reasons for new sponsors to join.

These are exciting times for the Joint Program, and critical times for global change research. We hope to see many of you in September in Banff at our next Sponsors Meeting and Global Change Forum. Feedback on our new communication initiatives or any thoughts you have on the Program are always welcome.

With very best regards,

Ron Prinn John Reilly

New!

Sponsors Webinar Series

The Sponsors Webinars continued this season with Adam Schlosser presenting on arctic ecosystems, and Sergey Paltsev presenting on long-term trends in natural gas.

For those who missed them, they are available on the sponsors-only website at: http://globalchange.mit.edu/sponsors-only/webinar.html.

Pre-Release Publications & Discussion Board

Visit these new features on the sponsors website. Alerts are sent via email when these pages are updated. Not receiving them? Need others to have access?

Contact Vicki Ekstrom at: vekstrom@mit.edu.

XXXIV MIT Global Change Forum and Sponsors Meeting

Date: **September 26—28, 2012**
Place: **Banff, Alberta, Canada**
Theme: **The Role of Fossil Fuels in the Transition Toward a Low Carbon Future.**
Forum attendance is by invitation and pre-registration only. If you have not registered, please contact Frances Goldstein at: fkg@mit.edu.

Getting the Price Right on Climate

An IMF-MIT study shows immediate –but realistic–actions are needed to confront climate change.

As global leaders prepared for the Rio+20 sustainable development summit in Brazil in June, the International Monetary Fund (IMF) and a collection of economists from MIT and other organizations released a report to help leaders confront the price tag associated with climate change. The publication—Fiscal Policy to Mitigate Climate Change: A Guide for Policymakers—details the most effective methods to reduce emissions and contain costs, namely through carbon pricing.

Until now, leaders have focused on slowing warming to 2 degrees Celsius to prevent catastrophic changes associated with climate change. Because this would mean taking drastic measures to hold emissions at about today's levels, researchers at MIT argue that leaders should be realistic and start smaller because the time to act is quickly running out. Their research—Emissions Pricing to Stabilize Global Climate—is a chapter within the IMF guide.

"Negotiations on the exact emission reduction target have been going on for a long time without much substantial progress," says Sergey Paltsev, lead author of the MIT study and associate director for economic research at the Joint Program on the Science and Policy of Global Change. "But it is better to start with some policy that reduces emissions because even a small initial step is important as it sets the process on track."

IMF's Managing Director Christine Lagarde points to a tax or trade system.

"Perhaps we can help with a simple concept that everybody can understand—getting the prices right," Lagarde said in a speech at the Center for Global Development. "Getting the prices right means using fiscal policy to make sure that the harm we do is reflected in the prices we pay. I am thinking about environmental taxes or emissions trading systems under which governments issue—and preferably sell—pollution rights."

The MIT research suggests an emissions price—organized through either a tax or cap-and-trade system—of about $20 to $40 per ton by 2020 to help the world community reach less stringent targets that would keep warming to 2.9 or 3.6 degrees Celsius.

"These less stringent targets are more realistic and reachable, and they still reduce the risk of more severe climate impacts," Paltsev says. But, he warns, "we have never experienced such changes and do not know exactly how the Earth will respond, so the smaller the changes we make, the greater the risk of something unexpected and bad happening."

Still, making small changes is better than not acting at all, Paltsev says, and we shouldn't wait for technology to fix the problem for us.

"We can wait for a miracle technology, like biofuels with carbon capture and storage, to appear and become economical—allowing us to reach more stringent targets—but then we place our bets on something which may or may not materialize," Paltsev says.

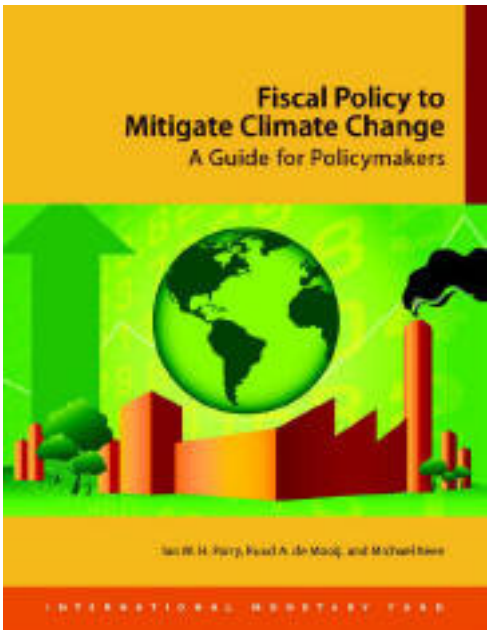
The longer the global community waits to take action, the higher the price tag could be and the less likely the world will be able to meet even less stringent targets. This could mean "unprecedented levels of damage and degradation" if current trends in production and consumption continue, United Nations Undersecretary General Achim Steiner said in a recent statement. He added, "The moment has come to put away the paralysis of indecision, acknowledge the facts and face up to the common humanity that unites all peoples."

Andrew Steer, special envoy for climate change for the World Bank, agrees.

"We will turn the tide against climate change only when core economic policymakers wake up to the urgency of the issue and factor it into their fiscal and economic policies," he said.

Making progress one step at a time

Even if all countries were able to agree on a uniform path forward, slowing emissions would require a complex burden-sharing system including incentives and compensation for emerging and developing countries—continuing an ongoing struggle about who pays what to confront the challenge.



Read the full IMF book at: http://www.imf.org/external/np/seminars/eng/2012/rio.

While such an international effort may take time, the Green Climate Fund—formed in Cancun, Mexico, in 2010—could help developing countries. Meanwhile, major emitters like the United States, European Union and China could establish a relatively small carbon tax, the revenue from which could be returned to citizens to balance out the higher energy prices and increase public support. The idea is similar to parts of a proposal by United States Sen. Maria Cantwell (D-Wash.).

Still, cap-and-trade—a system invented by American economists—is far from being implemented in the United States, as countries around the world take steps to implement the system—like China.

"Just as many of our best innovations are produced in China, they may beat us in implementing such a system," John Reilly, a co-director of the MIT Joint Program on the Science and Policy of Global Change and an author of the IMF chapter, said recently. "We're really being left behind."

China is not the only country that has an edge on the United States. The EU, Australia, New Zealand and South Korea have already begun to set hard emission limits, and cap-and-trade programs are gaining traction in Brazil and Mexico as well.

Joëlle Chassard, manager of the Carbon Finance Unit of the World Bank, said in a statement that it was heartening to "see increasing interest in, and support for, new market-based mechanisms to mitigate climate change."

Paltsev agrees that these systems are encouraging and useful, even at the local level. But, he says, "It is also important to harmonize the efforts" and "all major emitters, including the U.S., need to participate." ■

V. Bosetti, S. Paltsev, J. Reilly, and C. Carraro, Emissions Pricing to Stabilize Global Climate, *Fiscal Policy to Mitigate Climate Change: A Guide for Policymakers, International Monetary Fund*, June 2012.

LATEST NEWS

Read our latest news on the In the News page of our new website: http://globalchange.mit.edu/news-events/news.
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Double the Benefits: Clean Energy Also Saves Water

NREL-MIT study shows an 80 percent renewable energy standard cuts water use in half.

In his first State of the Union address, President Barack Obama set a goal for 80 percent of America's electricity to come from clean energy. The release in June of the Renewable Electricity Future study by the U.S. National Renewable Energy Laboratory (NREL) confirms that reaching this goal by 2050 is very possible. But what impact would clean energy have on another key ingredient to daily life: clean water? Researchers at MIT helped answer that question in NREL's report.

The MIT research—The Impact of Renewable Electricity Futures on Water Demand—is a compilation of the water segment of the Renewable Electricity Future study. In it, the researchers find that as solar panels, wind turbines and other sources of non-thermal renewable energy replace coal, gas and similar thermal powerplants, the use of water to cool those powerplants will decrease by about half.

"The most important use of water for electricity production is for cooling," says Adam Schlosser, an author of the study and the assistant director for science research at MIT's Joint Program on the Science and Policy of Global Change. "The benefit of renewables like wind or solar is that you don't need to boil water for steam to spin the turbines, and then you don't need water to cool the steam. That cooling process is removed, saving a lot of water."

This is good news for water-stressed regions, including much of the western United States, as production of electrical power results in one of the largest uses of water in the nation. A 2005 report by the U.S. Geological Survey found that about 201,000 million gallons of water each day were used to produce electricity, with much of this water going toward keeping powerplants cool.

While most Americans will use less water when powering their homes with renewable energy, the MIT researchers did find that areas that switch to thermal renewable technologies might end up using more water. Biomass energy, being produced mostly in the northwestern United States, is one strong example, the study finds.

"Biomass is obviously contributing to the carbon aspect of the overall problem," Schlosser says, "But it's actually exacerbating an already water-stressed situation because you not only need water to grow it, you also need water to cool the thermal electricity generation process."

Schlosser compares this to concentrated solar technology being used in the southwest, which typically relies on a dry cooling system where fans are used instead of water.

"Solar technology really benefits the southwest because it uses a resource that's so plentiful in that region—the sun—and doesn't use a resource that there is very little of—water," Schlosser says.

But Schlosser explains that the dry cooling technology—while an obvious choice for the drought-stricken southwestern United States because it uses 90 percent less water—is less efficient and more expensive because the electric plant would need to use electricity to run large fans that force air through the heat-exchange process. This explains why areas where water scarcity is more subtle would choose to stick to water cooling technologies in thermal electricity generation.

Along with using less water, the Renewable Electricity Future study finds that greenhouse gas emissions would be reduced by about 80 percent, potentially offering significant public health benefits. The National Research Council estimated that in 2005, air pollution emissions from coal powerplants cost $32 per megawatt of energy in public health damages, the report notes, suggesting that the health cost benefits could counterbalance the costs to build clean energy infrastructure. ■

K. Strzepek, J. Baker, W. Farmer, and C. A. Schlosser, Modeling Water Withdrawal and Consumption for Electricity Generation in the United States, *JP Report 222*, June 2012.

Related Research

Three Questions with Research Scientist Sebastian Rausch

Before leaving the Joint Program this summer, researcher Sebastian Rausch sat down with us to talk about his latest work studying the pros and cons of a renewable energy standard versus a carbon tax.

Q: What is the relevance of the study (*JP Report 225*) in today's political environment?

A: Since the U.S. cap-and-trade bill failed in 2010, there have been repeated calls to curb emissions in the U.S.—leading President Obama to set an 80 percent clean energy goal. Establishing a Clean Energy Standard—which, along with including renewable sources, would also include gas and nuclear and give partial credit to carbon capture and storage—has been considered critical to achieving that goal and has gained significant bipartisan support. The National Renewable Energy Laboratory also released a study, which some of my colleagues participated in, that showed achieving a Renewable Energy Standard is very doable.

Given this context, we decided to study the impacts of clean and renewable energy standards in the U.S., especially in comparison to a carbon tax. Our work is the first to link a "bottom-up" approach that contains a detailed look at the electricity sector with a "top-down" general equilibrium model. This allows us to detect regional electricity demand factors and their effects on the broader economic system. It also allows us to measure how different regions and income brackets are affected. While we looked specifically at the U.S., some of our results could apply to other countries as well.

Q: How did the renewable electricity standard stack up against a carbon tax?

A: Looking at both a clean energy standard—similar to President Obama's proposal—and a renewable energy standard that sets a 70 percent mandate, both would significantly reduce CO_2 emissions. In fact, in the case of the clean energy standard, emissions would be cut in half. But these policies also cost a lot more than a carbon tax or cap-and-trade policy. The renewable energy standard would cost four times more, while the clean energy standard would cost a little less because it allows for cheaper forms of energy like gas and nuclear.

Q: Who will be impacted the most from the higher price tag?

A: Both clean and renewable energy standards place a greater burden on low-income households because they spend a larger fraction of their income on electricity. This is really a problem because these standards don't generate any revenue to subsidize the difference, unlike a cap-and-trade or carbon tax. Regionally, those who have traditionally relied on low-cost electricity from coal will see their electricity bills increase as their electricity sources switch from coal to more expensive forms of energy. But compared to regions that have always paid a higher price tag, these bills will remain lower. Places where there are abundant supplies, or at least potentially abundant supplies, of hydro power, wind and solar will see the burden.

S. Rausch and M. Mowers, Distributional and Efficiency Impact of Clean and Renewable Energy Standards for Electricity, *JP Report 225*, July 2012.

SPONSOR EXCLUSIVE: Visit the sponsors-only website's Pre-Release Publications page for research summaries before they are published: http://globalchange.mit.edu/sponsors-only/publications.

The Impact of Melting Ice on Global Emissions

New research adds to a growing debate on the impact of thawing permafrost, and the associated carbon and methane emissions it would release, on our warming planet.

Meet the Researcher

Xiang Gao is a research scientist for the Joint Program. Her work focuses on the development and application of land-surface models and the use of satellite remote sensing data to investigate land-climate interactions, the global water cycle, vegetation, and Arctic processes. Prior to joining MIT, Dr. Gao was a research scientist at the Center for Ocean Land Atmosphere Studies (COLA) in Calverton, Maryland.

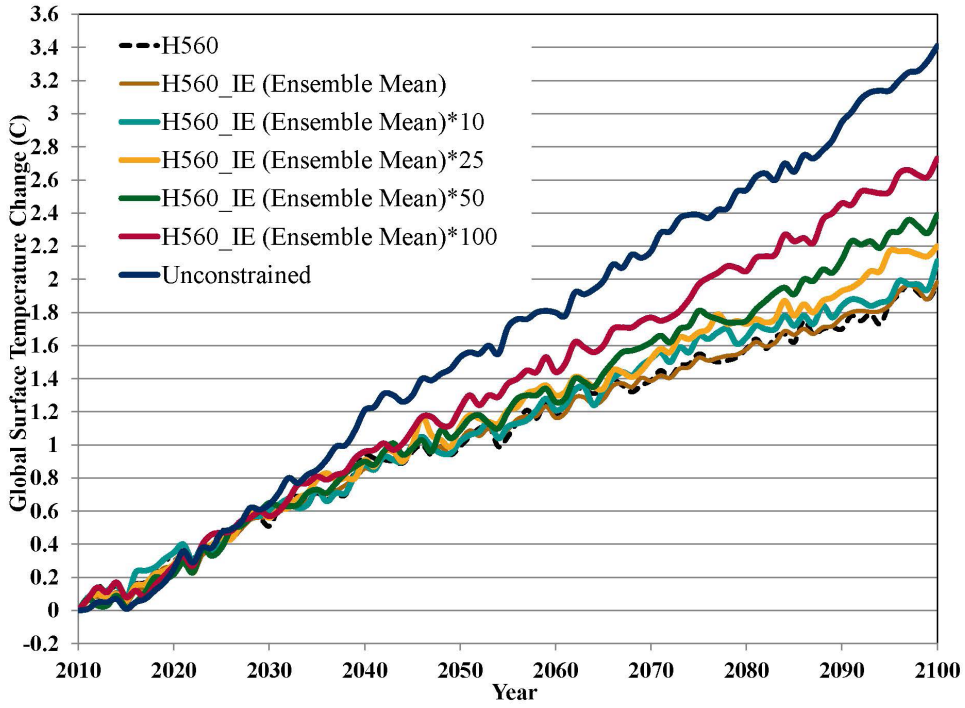
The study—Permafrost, Lakes, and Climate-Warming Methane Feedback: What is the Worst We Can Expect? (*JP Report 218*)—finds that permafrost has a high concentration of carbon locked within it. When it melts, this permafrost forms lakes and the carbon releases from those lakes in the form of methane. This methane is even more potent than carbon, raising the intensity of the warming. Over the next century, the research shows that methane could increase as much as 237 percent.

While this is a substantial amount of emissions, in comparison to global human-induced emissions, this methane would contribute at most about 0.1° Celsius of global warming—and that is only if policies are in place to constrain emissions. In an unconstrained, business-as-usual scenario, the methane emissions from the permafrost have almost no effect on global warming because those emissions would be such a small fraction of total emissions.

"The only way we could see these methane emissions as having any noticeable impact on global warming is if every nation adopted very stringent policies to reduce their emissions," said Xiang Gao, the lead author of the study and a research scientist at MIT's Joint Program on the Science and Policy of Global Change. "Otherwise, the methane emissions—while substantial—are such a small fraction of the vast, world-wide emissions that they have almost no affect."

These findings join a number of other studies in countering an opposing view released in *Nature* last November. The November study made headlines after the authors claimed melting permafrost would speed up warming by up to 30 percent because of the release of carbon and methane currently locked away in the ice and land. The scientists in the study predicted that over the next three decades a total of about 45 billion metric tons of carbon and methane would seep into the atmosphere when the permafrost thaws—the equivalent to five years of burning fossil fuels.

Methane Emissions from Permafrost



If methane emissions were 100 times greater than predicted, they would contribute an added 0.8° C of warming.

If methane emissions were 25 times greater than predicted they would contribute an added 0.2° C of warming.

Methane would contribute at most about 0.1° C of global warming with policy, and have almost no effect without policy.

"I would agree with the authors that these ecosystems remain insufficiently observed, and there remains a sizable gap not only in our understanding of the biogeochemical mechanism [carbon, methane] but also the hydrologic response," said Adam Schlosser, a co-author of the MIT study and the assistant director for science research at the Joint Program on Global Change. "But in all of our cases considered, and under the full range of uncertainty in the earth-system response, we do not find evidence of a salient temperature feedback due to the methane emissions."

Seeing such a small impact the methane emissions would have, the MIT researchers measured the global warming impact if those emissions were 10-, 25-, 50- and 100-fold greater than they were predicting. Their findings showed that the methane would need to increase by a magnitude of 100-fold more than what they predicted, in a scenario where emissions were constrained by stringent policy, to have a notable impact on global climate—with the methane contributing about 0.8° Celsius of the total warming.

While the findings show methane emissions from melting permafrost would have very little, if any, impact on global warming, the researchers warn that widespread permafrost thaw may still have a significant impact in the arctic and subarctic region—a region already showing signs of more intense warming than the rest of the globe. The researchers intend to use their integrated climate model to look more closely at the regional impacts of carbon and methane emissions released from melting ice. ■

X. Gao, C.A. Schlosser, A. Sokolov, K. W. Anthony, Q. Zhuang and D.W. Kicklighter, Permafrost, Lakes, and Climate-Warming Methane Feedback: What is the Worst We Can Expect? *JP Report 218*, May 2012.

SPONSOR EXCLUSIVE
Assistant Director for Science Research Adam Schlosser covered this topic and more in a Sponsors Webinar in Febuary. If you have not seen it, view it now on the sponsors-only website: http://globalchange.mit.edu/sponsors-only/webinar.

Seeing Green: Saving Forests or Food Prices?

A growing population and rapid development will put a strain on land used to grow food over this century. But if reforestation is used to avoid climate change it will create further strain, says MIT study.

It's no surprise the U.S. and China are the world's top greenhouse-gas emitters. What may be surprising is the country that ranks third: Indonesia. Why? Because of its massive deforestation.

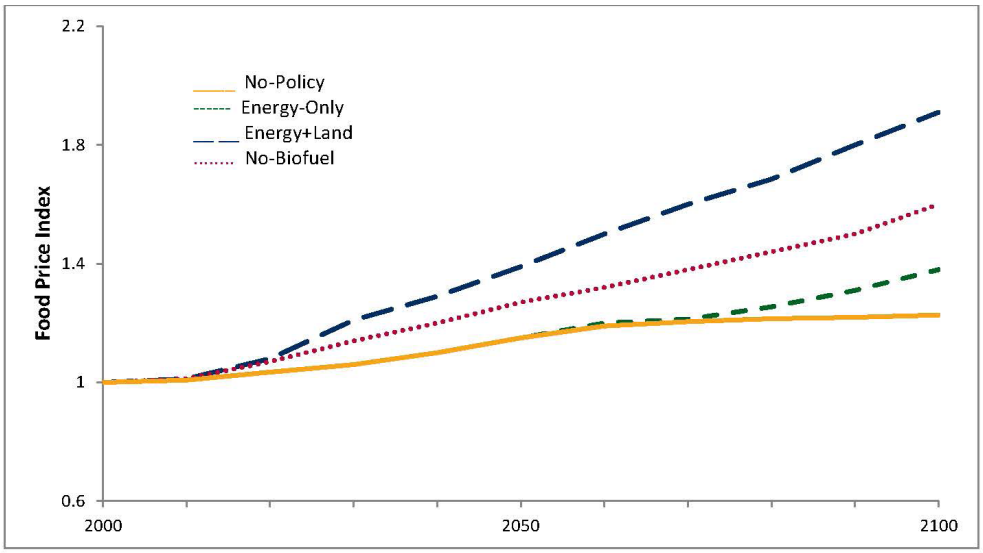
Deforestation accounts for almost 20 percent of global emissions—more than the world's entire transportation sector. But saving the trees—beneficial to the changing climate—comes at a steep cost as a growing, wealthier population competes for food, says a new MIT study.

"With a larger and wealthier population, both energy and food demand will grow," says John Reilly, the study's lead author. "Absent controls on greenhouse gases, we will see more emissions from fossil-fuel use and land-use change—reducing crop yields and requiring even more land for crops. This could become a vicious circle."

The Reilly et al. study compares the effects of slashing emissions from energy sources alone to a strategy that also incorporates land-use emissions.

The report finds, even with an aggressive global tax on energy emissions, the planet will not be able to limit warming to 2° C—the target leaders agree is needed to avoid dangerous climate change.

Food Prices Increase Under Various Scenarios



Food prices could rise more than 80 percent due to higher energy costs under a policy where emissions from energy and land are constrained.

When the tax is applied to land-use emissions, the world community could come much closer. The world could come much closer still by incorporating biofuels production and economic incentives for storing carbon on land, such as through reforestation.

But there are always drawbacks.

"The environmental change avoided by reducing greenhouse-gas emissions is substantial and actually means less land used for crops," Reilly says. "The big tradeoff is that diverting this amount of land to carbon storage, and using land to produce biofuels, leads to substantial rises in food and forestry prices." ■

J. Reilly, J. Melillo, Y. Cai, D. Kicklighter, A. Gurgel, S. Paltsev, T. Cronin, A. Sokolov and A. Schlosser, Using Land to Mitigate Climate Change: Hitting the Target, Recognizing the Trade-offs, *Environmental Science and Technology*, March 2012.

No Crystal Ball for Natural Gas

Traditionally, oil prices have been used to gauge the natural gas market; but new research shows the future of what is now a cheap fuel is really anyone's guess.

Natural gas prices neared the lowest they've been in about a decade this past winter, as utilities scrambled to take advantage of the fuel's low price tag and producers began to turn away from the low-profit fuel. According to the U.S. Energy Information Administration, the proportion of gas used to generate electricity soared to almost 35 percent in February—the highest ever for that month—while production saw its biggest decline in a year. These factors have led some to believe prices will rise again, and soon. Not so fast, say researchers at MIT.

Their study shows a relationship between the pricing of oil and gas from the early 1990s to today. But the nature of that relationship is constantly changing and is subject to external pressures, making it difficult—if not impossible—to predict the price.

"The tie between gas and oil has been exaggerated," says researcher John Parsons, one of the study's authors. "Parity will get re-established, but it might take a long time and it might be at a different level than you thought."

Besides the price of oil, two forces heavily influence the gas market: long-term forces, like technological change, and short-term volatility due mostly to weather or seasonal changes. Both forces are at work today, as prices have fallen from $10 back in 2008 to $4 last fall to about $2.40 this spring.

Parsons attributes a majority of the recent drop to weather, but points to hydraulic fracturing (fracking)—along with factors like the global recession—as the cause of the much larger drop over time. He says the price may recover from the short-term drop quickly—perhaps back to $4 in just a couple years—but price recovery from the effects of fracking could take longer.

"And so the danger is that we say there's parity" between oil and gas prices, Parsons says, "and it gives people the impression that the parity establishes itself quickly and they discount the price signal and try to keep going with producing gas."

This happened when prices fell in the past: producers were slow to take the price fall seriously because of the usual short-term volatility attributed to weather and seasonal changes.

How the gas market will shape up in the long term is anyone's guess, Parsons says, largely because untapped resources are a wild card. Right now, the U.S. has a very cheap resource that provides a short-term cushion of low-priced gas. If hydraulic fracturing turns out to have limited applications, gas prices probably won't stay low for very long. But if other parts of the world rich in gas choose to use hydraulic fracturing, gas could turn into a revolutionary fuel, he says. That will "affect the price of gas and the price of oil and the pattern of electricity production globally," Parsons says. "But none of us know." ■

Ramberg, D. and J. Parsons, The Weak Tie Between Natural Gas and Oil Prices, *The Energy Journal*, 2012.

SPONSOR EXCLUSIVE

Assistant Director for Economic Research Sergey Paltsev talked about natural gas in a Sponsors Webinar in June. View it now on the sponsors-only website: http://globalchange.mit.edu/sponsors-only/webinar.

China Energy and Climate Project

First Annual Meeting Spotlights Progress, Collaboration

With a growing, wealthier population, China has become the world's largest energy consumer—and with it, the world's greatest source of greenhouse gas emissions. The inescapable importance of China to global energy and climate efforts has compelled the Joint Program—in collaboration with Tsinghua University—to zero in on the nation through a special China Energy and Climate Project.

Top: Researchers from the Joint Program and Tsinghua University pose at the First Annual Meeting in Beijing, China in May. The researchers are working together to form the China Energy and Climate Project.

Right: Joint Program Co-Director John Reilly opens the annual meeting.

Photos: Valerie Karplus

The China Energy and Climate Project held its First Annual Stakeholders Meeting this May in Beijing, China. The meeting, which attracted high-level government leaders and distinguished researchers from throughout the world, will be the Project's main vehicle for communicating results going forward. It was followed by a closed-door Sponsors' meeting—including founding partners ICF International, AFD, Eni and Shell—to discuss the latest research results in detail and directions for future work.

The leaders of the two parent organizations collaborating on the Project, Joint Program Co-Director John Reilly and the director of Tsinghua's Institute for Energy, Environment and Economy, Zhang Xiliang, were the main presenters at the May 17th stakeholder meeting. One focus of the meeting was to outline the objectives of the Project.

"China has become one of the most important economies

in the world, and certainly in terms of energy and greenhouse gas emissions," Reilly said. "This project will help transfer knowledge of what we have learned in Europe and the United States on energy and greenhouse gas mitigation to China's policymakers, help them understand what is happening in the U.S. and Europe, and how our economies and efforts to limit global environmental change are linked. It will also help to develop a better understanding by industry and policymakers outside of China of what is happening there. We expect two-way learning, and with a shared view of the problem a better chance for a global solution."

Along with reviewing the objectives, structure and timeline of the Project, Reilly and Xiliang showcased the capabilities of the two new research models developed in just nine months, and their practical use to help government and industry leaders make important policy decisions.

"Models that capture the unique features of China's economy and energy system are essential to inform the policy discussion in China," Prof. Zhang said. "The tools that our collaborative research team is developing will have a big impact on the policy process here."

Becoming a Sponsor

The China Project is separately funded from the Joint Program. To receive the added benefits of sponsorship, consider becoming a sponsor. Learn more: https://globalchange.mit.edu/CECP/.

The China-Global Energy Model (C-GEM) and China Regional Energy Model (C-REM) are being used to assess the impacts of various climate and energy policies described under China's Twelfth Five-Year Plan, along with other policies such as managed electricity and fuel prices, production incentives for state-owned enterprises, and the implications of rapid changes in China's economic structure, urbanization and wealth. While the China-Global Energy Model represents China as a single region and includes detailed global regions, the China Regional Energy Model includes individual provinces within China but aggregates the rest of the world into just a few regions (the U.S., Europe and Rest of the World).

Along with presenting details about the models, Reilly and Xiliang summarized other objectives of the Project, including the use of MIT's Emissions Prediction and Policy Analysis (EPPA) model to study the impact of transportation, energy and pollution reduction policies. The researchers involved in the project will also analyze sector-specific sources of carbon in China's trade and the impacts of policies design to reduce China's energy-intensive exports.

The government officials present at the meeting—which included the Deputy Director of China's National Development and Reform Commission Zhen Sun, and the Sector Chiefs for the country's National Energy Administration, Ministry of Industry and Information Technology, Ministry of Science and Technology and National Natural Science Foundation of China—provided feedback on the results so far. Each member indicated the new developments represented an important set of tools that were strongly needed to address complex questions facing policymakers.

"The meeting established a strong and candid dialogue between our team and China's leading energy and climate policymakers," Project Director Valerie Karplus said. "By understanding policy priorities and concerns, we can improve the communication of our results, as well as gain new ideas for future research. We look forward to another dynamic and productive year."■

Report: China's Actions are Crucial on Climate Change

Research shows China's impact on climate change, as well as its potential to shape the path forward.

When climate negotiators met in Bonn, Germany in May a major point of contention was who needs to do what to slow global warming. Nations such as China and the United States have held back from making substantial emission reduction pledges in the past, as both nations waited for the other to act. But new research out of MIT shows the importance of all major nations taking part in global efforts to reduce emissions—and in particular, finds China's role to be crucial.

The report—The Role of China in Mitigating Climate Change—published in the journal Energy Economics, compares the impact of a stringent emissions reduction policy with and without China's participation. It finds that China's actions are "essential."

"As the largest greenhouse gas emitter in the world, without China, climate goals—like the 2 degrees Celsius target that most agree is necessary to prevent serious irreversible consequences—are out of reach," says Sergey Paltsev, the lead author of the study and the assistant director for economic research at the Joint Program.

Specifically, the study finds that with China's help the global community is able to limit warming to 2 degrees Celsius, relative to pre-industrial levels. But without China, we miss that mark by about 1 degree Celsius. Not only will it be close to impossible to achieve the 2 degrees mark without China's participation, but emissions reductions will also be more expensive because substantial costs would shift to only some countries. That is why the researchers argue for a global economy-wide greenhouse gas tax that spreads the burden of responsibility.

China Energy and Climate Project

But even in this best-case scenario, reducing emissions comes with a steep price tag. China could experience substantial GDP losses by the end of the century under the most stringent policy cases. These losses come from higher energy prices, which influence consumption and export dynamics.

"While strong reductions may turn out to be costly in China and may require some incentives from developed countries," Paltsev says, "that doesn't make China's actions any less important."

The researchers stress, however, that reaching that 2 degrees threshold with China's participation is only possible in the most optimistic case—and these days, there isn't much cause for optimism. The researchers tested various levels of emission reduction plans—a global carbon tax of $10, $30 or $50. The various taxes would slow warming to 3.5, 2.4 and 2 degrees, respectively, by the end of the century, according to their analysis. With no global policy, the increase in warming is projected to be about 5.5 degrees Celsius. These scenarios show that, "Even more modest and realistic goals require near universal participation of major greenhouse gas emitters," Paltsev says.

Top energy user today, climate leader tomorrow?

The importance of China's participation in a global climate treaty increases with each year, as the country's population, economy and energy use continue to grow rapidly. From 2000 to 2010, China's energy use grew 130 percent. That's up from a growth of just 50 percent the previous decade. With a growing, wealthier population, China has become the world's largest energy consumer—and with it, the world's greatest source of greenhouse gas emissions.

China's share of global energy-related CO_2 emissions has increased in just eight years from 14 percent in 2000 to 22 percent in 2008. Eighty percent of those emissions came from coal, making China the consumer of about half the world's coal. But China is on a path toward doing something about their rapidly escalating energy use and emissions. They've recently announced they will be testing a pilot cap-and-trade program in select major cities in 2013, and plan to make the program national by 2015.

John Reilly, the co-director of the Joint Program on Global Change, pointed out recently the irony behind the plan. While the United States created the idea of cap and trade, he says, "just as many of our best innovations are produced in China, they may beat us in implementing such a system... we're really being left behind."

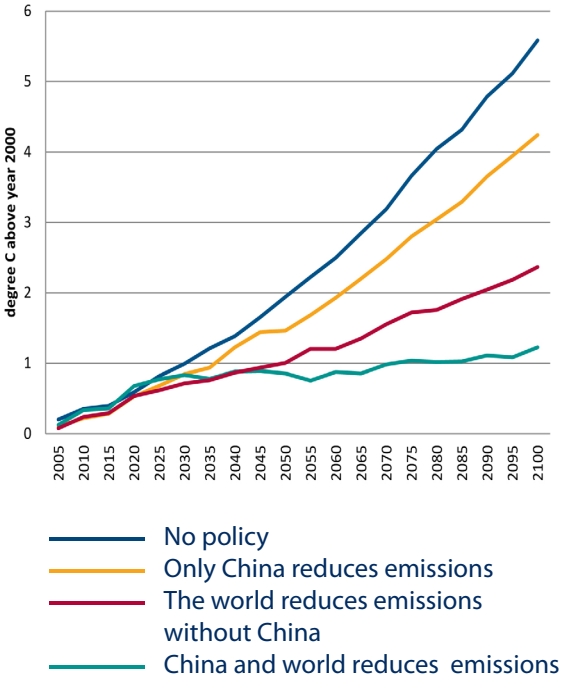
Paltsev agrees that the system would be "a very good start" for China, allowing the country to reach its goal of reducing carbon intensity by 40 percent relative to 2005, and increasing the share of non-fossil fuels by 15 percent by 2020. But, he says, "these actions are still not enough, making almost no substantial difference in reducing global emissions."

In fact, the change, taken by China alone, would only reduce global temperature by about 0.1 degree Celsius in 2020. But Tim Yeo, who chairs the United Kingdom Parliament's energy committee, recently told The Financial Times that if China did impose a national cap and trade system, "It's game over for the rest of the world ... Everyone will have to do it, including the U.S."

Paltsev agrees. "While the system would only be a start for China, as the country would still have a long way to go in reducing emissions, it would likely influence other countries—like the U.S.—to follow. But time is really of the essence." ■

S. Paltsev, J. Morris, Y. Cai, V. Karplus, and H. Jacoby, The Role of China in Mitigating Climate Change, *Energy Economics*, 2012.

Temperature Increase with and without China's Participation in Global Policy



Three Questions: Professor Ron Prinn

Earth System Models

Q: Why do we need Earth System Models?

A: In laboratory science, we have the luxury of running "control" experiments in which selected conditions that would otherwise influence the "main" experiment are omitted. In the case of our environment, the influencing conditions come from humans. Because we do not have another earth without human influence to serve as a "control," we often cannot directly measure the impacts of human development on the environment. So we form computer models of the combined natural and human systems, compare the models with observations, and then apply the models as "numerical control" experiments. Sergey Paltsev has already described what makes our specific earth system model—the Integrated Global System Model (IGSM)—so unique, as it combines the human system with the natural system to see how the two systems impact each other for the purpose of improving our understanding of both systems and informing policy decisions (See upcoming peer-review publication "Valuing Climate Impacts in Integrated Assessment Models: The MIT IGSM"). The IGSM is in fact a "framework" of linked sub-models of varying complexity with the choice of the sub-models being governed by the issues being addressed; uncertainty studies dictate use of the most computationally efficient models, whereas studies of specific scenarios allow use of the more complex but computationally demanding sub-models.

Q: What is the value of integrated Earth System Models like the IGSM, as opposed to other approaches, for those making decisions about climate mitigation and adaptation?

A: Applied, for example, to the climate issue, the IGSM framework allows us to determine, in a self-consistent way, the probabilities of various amounts of climate change, the relationship between greenhouse gas reduction targets and temperature changes, and the uncertainty in the costs of various proposed policies. The IGSM framework also enables integrated assessments of the economic and environmental implications of proposed new low emission energy technologies. In making these analyses, we are able to help decision-makers compare the value of various mitigation policies, energy technologies, and adaptation strategies in lowering the risks to society. We can also assess the costs for stabilization of greenhouse gases at various levels, and how these costs can be justified by the expected benefits from the avoided damages.

Q: What can the MIT IGSM tell us about our climate and energy future?

A: In this paper, I outline just some of the ways we've used the full IGSM framework, or the relevant parts of it, in the past. These uses include the examination of the effect of different greenhouse gas stabilization targets on forecasts of the odds of various amounts of temperature, precipitation, sea-level, and sea-ice change, and of the costs of these stabilization policies. Also, the relationship between stabilization targets and the future loss of the ability of the oceans to slow warming by absorbing heat and carbon dioxide has been examined. The Kyoto Protocol uses a CO_2-only strategy to reduce emissions, and our work with the IGSM shows that a multi-gas control strategy greatly reduces the costs of fulfilling the Kyoto Protocol with little difference between the two strategies in mitigating climate and ecosystem impacts. Assessments of the substantial impact of air pollution on human health costs and carbon uptake by land vegetation have been investigated. Another example stems from our work in examining the consequences of renewable energy at large scales—like wind power and bio-fuels. Our studies of wind power show that offshore wind turbines can cause a surface cooling over the installed regions due to an increase in turbulent mixing caused by the turbines. Additionally, while wind power is an important renewable resource for our future, it suffers from significant intermittency caused by large seasonal wind variations over most major offshore sites. We're expanding on this research to measure wind power intermittency over land in the U.S. Stay tuned for that study. ■

R.G. Prinn, Development and Application of Earth System Models, *Proceedings of the National Academy of Sciences*, 2012: http://globalchange.mit.edu/research/publications/2291.

Student Spotlights

Three Joint Program research associates received their Masters degrees in MIT's Technology and Policy Program this summer. Before they graduated, they shared what they've learned, what they'll miss, and what they'll take with them throughout their careers after leaving the Joint Program.

Megan Lickley: Adapting Energy Infrastructure to a Flood of Uncertainty

We may always crowd stores for last-minute essentials before a storm. But how can we prepare years, and even decades, ahead of the next big one? Megan Lickley is shedding a little light for the energy sector before she leaves MIT.

"As we saw during Hurricane Katrina, severe storms have major consequences on energy facilities, specifically through storm-induced flooding ," Lickley says. "As sea level rises and storms become more severe, the risk to these facilities will likely increase. We need to decide how or if we're going to adapt to these changing risks. Should facilities be protected, or abandoned, or should we continue with business as usual? These are decisions that need to be made. We can't really make these decisions if we don't have an understanding of how the risks are actually changing."

Studying the impacts of hurricanes and sea level rise on coastal energy infrastructure—and specifically in the energy hub of Galveston, Texas—Lickley looked at the change in the risk of flooding 100 years from now. By isolating her analysis to a single facility, she developed a risk analysis that included the changes in risks from tropical storms, sea level rise and subsidence, and further developed a framework to help decision makers make the best decisions to adapt to the changing risks. These risks vary depending on location and time-frame. For her case study of a facility at five feet above sea level, Lickley found that risks increase from a one percent chance of flooding today to as much as a 45 percent chance of flooding in 2100.

Lickley says it's important for people to understand these risks and be ready ahead of time, especially considering the damage from Hurricane Katrina and New Orleans' reaction after that disaster.

"After a place has been struck, the fear factor is more vivid and the willingness to respond and plan ahead is much greater even though the risk isn't any higher," Lickley says, "Having public and political support is a critical part of actually adapting, but you don't want a place to be destroyed in order for them to want to protect themselves. Understanding the increased vulnerability and making decisions based on true risks will ensure the best results."

This research gives energy organizations some of the knowledge needed to act.

Lickley thanks MIT's Kerry Emanuel and Ning Lin for giving her the storm intensity data she needed, as well as her advisor Jake Jacoby for his support each step of the way.

As for what's next? Lickley hopes to continue doing collaborative research projects in the climate-energy realm—a future inspired by her work in the Joint Program, where she has enjoyed learning "a lot about different components of the climate change issue" from her fellow researchers. ■

Arthur Gueneau: The Impact of Climate Change on Agriculture

As Arthur Gueneau leaves MIT to explore greener pastures, he's leaving his mark on the agricultural world with a new model he's named after himself—well, kind of. The CLM_AG model—the product of his thesis—adds an agricultural component to the Community Land Model (CLM) currently woven into the Joint Program's IGSM.

"In the beginning I was taking CLM and putting A-G after it and people said, 'Oh A-G for agriculture.' Well, actually, it's my initials, but that works too," Gueneau said of his new creation.

While few will remember the true meaning behind the name, the model itself will be a lasting feature of the Joint Program's work. CLM_AG measures the impact of climate change on crop water stress and irrigation. Unlike in the past where the IGSM used a standardized crop formula, Gueneau's additions to the model allow it to look at the behaviors of different crops in different regions. For example, corn needs more water than cotton, and wheat is usually rain fed. These behavioral differences cause these crops to be impacted by climate change in different ways. The CLM_AG model is also more consistent in its equations and faster to run than the previous CliCrop model the program had been using.

Gueneau's thesis used CLM_AG for two main purposes. First, he used the model, along with the MIT IGSM-CAM climate model, to find out what impact climate change would have on the world's irrigation systems by 2050, both with and without mitigation policy. From this, Gueneau found that climate change surprisingly made it easier for some areas of the world to grow healthy crops because as it gets warmer evaporating water vapor could cause more rain. But, he warns, there is a lot of uncertainty from model to model and region to region. This led Gueneau to the second aspect of his thesis—an in-depth look at uncertainty in one specific region: Zambezi, Africa. He used 400 different variations of the model to learn which crops would have a greater risk of suffering from a lack of water. He found, for example, that corn in Zambezi may require up to 15 percent more water than it used to. But, Gueneau warns, there is still a high level of uncertainty.

How do you plan policy for that?

"It depends on what you want to do," Gueneau says. "Do you want to do something that's resilient? That means plan for the worst scenario because if the worst case happens and you're not prepared then you're in really bad shape. Or, do you want to be economically efficient? Then you should plan somewhere in the middle…You could also be the guy who's hiding behind his desk with his hands covering his eyes saying 'Oh, but there's still a 10 percent chance that it doesn't change.'"

The key, he says, is being able to adapt to climate change.

"The whole point is to be flexible. If you're planning an irrigation system, you should plan in the middle but keep the option open to be able to add a second pipe or raise the dam."

Gueneau's ongoing research on this topic will take him to Washington, DC, where he will be studying the impacts of climate change on agricultural policies at the International Food Policy Research Institute. As he departs for this adventure, Gueneau says he will always remember that progress takes collaboration—a lesson he learned from the Joint Program.

"This whole program is built on a system where groups of people who would have never talked to each other if it was up to nature come together," Gueneau says, "I've learned from this that everything is a system. Everything is connected. If you don't go outside your specific focus and talk to other people who are studying the same thing in a different way, you're missing the point." ■

RESEARCHER HIGHLIGHTS

Learn more about our researchers on the Researcher Highlights page: http://globalchange.mit.edu/about/our-people/researcher-highlights.

Paul Kishimoto: Peering into China's Future

Paul Kishimoto is intrigued by the question: How will we sustain the ways we move? To answer that, he's tackled an issue of great uncertainty and concern—specifically regarding China's transportation future.

With the number of cars sold in China each year having already surpassed that in the U.S. or Europe, and that trend increasing rapidly, many are worried. This trend means more emissions that contribute to health problems and global climate change, and also making the Chinese vulnerable to oil price shocks like the U.S. experienced in the 1970s.

The question in China is, when and how high will vehicle use peak? Because of the amount of uncertainty surrounding that question, Kishimoto used methods similar to those behind the Joint Program's Greenhouse Gamble wheels to test 400 possible outcomes and compare them to the past. The average outcome from these projections showed an increase in vehicle use from 50 to 600 cars for every thousand people by 2050 —with some cases falling below 600 and some rising above.

Reviewing the work of others, Kishimoto chose the highest vehicle use others have predicted, the lowest, and a medium result—with his likely uncertainty-based estimate agreeing with the highest vehicle use case (600 vehicles/1000 people). He then applied a policy measure to each of these scenarios to see what impact restricting emissions would have on future vehicle use. The high vehicle scenario dropped from 600 vehicles to just about 200 for every one thousand people. That's compared to places like Europe where car ownership has peaked at 600, and the U.S. where ownership is at 800 for every thousand people.

While the policy scenario modeled is strong, and perhaps unrealistic, China will have some climate policy. The government has already committed to reducing emissions intensity 17 percent by 2015, and 40—50 percent in total between 2005 and 2020. But how programs in different provinces play into the targets of China's central government brings in a new type of uncertainty.

"The average bureaucrat in China has a life that's pretty similar to the average middle class urban citizen, so if they're trying to get to work in the city and it's congested, or very smoggy, or their gas prices are high—they're bothered by that personally and that shows in the policies they pursue," Kishimoto says.

It's this dynamic that has led Shanghai, the second largest city in China after Beijing, to cap the number of cars allowed in the city by auctioning a limited number of license plates each year. An average license plate is about $10,000, about the same as a small car —forcing people to pay twice as much just to get on the road. That strategy has worked, as Shanghai adds only about 100,000 new vehicles each year, as opposed to about 300,000 in Beijing.

While the policy is in direct opposition to the central government's goal to grow the domestic auto industry, especially by subsidizing electric and hybrid vehicles, it's unclear if other smaller—but growing —Chinese cities will adopt a similar approach.

Regardless of how things turn out on the policy front, China's transportation growth over the next 50 years will not mirror that of the U.S. or Europe's growth during the last 50 to 100 years.

"While China is going through things the Western world went through almost a hundred years ago—industrialization and increased motorization, urbanization and people getting wealthier— because of different options available technologically and different policy considerations they're not going to take the exact same trajectories as the U.S. or Europe," Kishimoto says, "China has its own, unique transportation future."

As for Kishimoto future? Before pursuing a PhD, he plans to continue working with the Joint Program as a researcher on the China Energy and Climate Project.

"I still feel like I have a lot to learn from the people who are around me here," Kishimoto says, attributing that feeling partly to the general environment of the Joint Program. "We're all in one pool doing very different things, but we're all chipping away at the same problem… that helps you see how what you're doing can have a big impact." ■

Earth Month at MIT

MIT and the Global Change Joint Program hosted several visitors and special events for April's Earth Day festivities. Here are some of the highlights.

New York Times Dot Earth writer Andrew Revkin enouraged listeners to "get out of the nerd loop."

Communicating the Climate Challenge

Using new ways to confront persistent challenges is one of MIT's greatest strengths, and an idea reinforced at an event hosting the *New York Times* writer Andrew Revkin, author of the Dot Earth blog. Revkin's visit was part of an Earth Day colloquium hosted by the Joint Program, along with the MIT Energy Initiative and the Program in Atmospheres, Oceans, and Climate.

"There's never been a better time to share and shape and collaborate" to help communicate and confront complex challenges like climate change, Revkin said, because changes in the media have made it easier to share ideas. In this way, he said we're "moving toward having a planet of the mind." Right here on MIT's campus, the Climate CoLab specializes in this type of collaborative thinking, and is harnessing the collective intelligence of thousands of people around the world to collect proposed ways to take up addressing climate change.

Along with using new technology to develop collective thinking and discover best practices, Revkin said we also need to use new ways to explain challenges in the first place to gain more public understanding and support. He called this "getting out of the nerd loop." This idea of using visual tools to help explain climate change is something the Joint Program has done for years with its Greenhouse Gamble Wheels, which demonstrate the uncertainty of warming under policy and no-policy scenarios.

Whatever the topic, Revkin said the key to effectively communicating—and tackling—these challenges is having a "willingness to experiment with new ways to say the same thing." For students, that means "at least just touching the stove to learn that it's hot yourself, and not being fearful of experimenting … just because someone tells you it's scary."

Read more about the event, or watch the video: http://globalchange.mit.edu/news-events/news/news_id/174.

Our Gasoline-Free Future and How to Get There

With gasoline prices remaining unpredictable, Americans and automakers are investing in alternatives. But what's the most effective way forward? Toyota's VP for Technical and Regulatory Affairs Tom Stricker gave his take at an event co-sponsored by the Joint Program. Stricker focused on the Open Fuel Standard up for debate in Washington, which requires automakers to phase in cars capable of running on something other than just gasoline.

While advocates claim the flexible fuel vehicles would cost only about $100 more per vehicle, Stricker finds they would cost much more. He believes automakers should focus instead on more efficient vehicles rather than focusing on solutions technology could make obsolete before they get implemented.

Joint Program Co-Director John Reilly, MIT Professor Christopher Knittel and Toyota's Tom Stricker talk after the event.

Read more about the event, or watch the video in full: http://globalchange.mit.edu/news-events/news/news_id/173.

Facing the Facts About our Changing Climate

In an effort to share what is known, what isn't, and what can and cannot be done about climate change, MIT's John Reilly and Kerry Emanuel joined UMass Amherst researchers as part of a "Global Warning" panel convened by the Boston Globe's environment writer David Abel.

Joint Program Co-Director John Reilly and *Boston Globe* writer David Abel debate climate change at the Globe event.

Reilly pointed out that while the price of doing nothing about climate change is huge, the price of doing things inefficiently is also costing us.

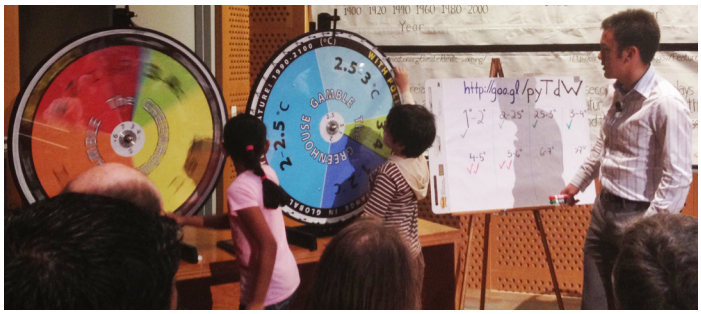
He contrasted a cap-and-trade system, or its rough equivalent a direct tax on greenhouse gases, with currently-proposed policy measures such as new vehicle fuel standards. He said these standards are inefficient because they only focus on new vehicles and they apply just to the transportation sector when the electricity sector makes up most of the emissions. They are also more expensive, Reilly said, noting that on our current path of using inefficient technology standards it would cost in the trillions of dollars between now and 2050 to reduce emissions by 30 percent. Under a greenhouse gas tax, that same reduction would cost about $500 billion.

"Is it worth it to accept GHG taxes to save several trillions of dollars? I think so," Reilly said. "But apparently people would like to hide the cost in government subsidies and other sorts of things rather than face the higher cost. These subsidies ultimately cost us as taxpayers. So we are paying a high price to not see the price we are really paying."

Read more about the event: http://globalchange.mit.edu/news-events/news/news_id/172.

Rivers of Ice

With the advisement of several Joint Program researchers —including Co-Director Ron Prinn and Co-Director Emeritus Jake Jacoby—the MIT Museum opened a new exhibition "Rivers of Ice: Vanishing Glaciers of the Greater Himalaya." Drawing from the photographs of mountaineer and filmmaker David Breashears, and comparing them to earlier photographs, the exhibit reveals the glacial melt that has occurred over time. It is an opportunity to educate people on the groundbreaking research being done to better understand the glaciers' potential impact on global environmental issues.



Joint Program Research Associate Paul Kishimoto explains the Greenhouse Gamble Wheels at the exhibit's opening.

The exhibit will be on display at the MIT Museum until March 17, 2013. Learn more: http://web.mit.edu/museum/exhibitions/rivers-of-ice.html.

Powering the Chinese Dragon

Just weeks after an MIT report showed fast-growing nations like China would drive energy growth over the next half century, MIT received a visit from a leading company powering that growth: CLP Holdings (China Light & Power since 1901) Peter Littlewood. The event, co-sponsored by the Joint Program, focused heavily on China's growth and its relationship with the United States.

CLP Holdings Peter Littlewood.

"The U.S. is the most creative place in the world. This is where we come for good ideas. This is where we come to see into the future," Littlewood said. "China is where products get financed, where equity comes from, and where manufacturing takes place at the lowest possible cost. You could say the U.S. is the front office, China is the back office. The U.S. finds solutions, China develops them."

Read more about the event: http://globalchange.mit.edu/news-events/news/news_id/169.

Welcome Véronique Bugnion!

Bringing with her more than a decade of financial energy experience, Véronique Bugnion officially began working for the Joint Program this summer. She looks forward to applying her knowledge as a scientist, entrepreneur and energy industry leader to her work with sponsors and prospective sponsors as assistant director of program development.

Bugnion comes to the Joint Program from Thomson Reuters, where she was the global head of carbon and natural gas and developed trading, data and research products for wholesale commodity markets. Thomson Reuters acquired Point Carbon in 2010, where Bugnion developed advanced web-based analytic products for the electricity, natural gas and carbon markets. She continues to push the boundaries of energy analytics as co-founder and co-CEO of ClearlyEnergy, a provider of innovative search solutions to simplify energy decision making. Bugnion began her career as an associate at Goldman Sachs and spent three years as a vice president at Constellation, where she focused on the deregulated power, natural gas and emissions markets.

The Joint Program is not new to Bugnion. She worked with the Program while attending MIT for her doctorate in climate physics and chemistry and masters in technology and policy, and has a strong publication record in climate modeling and climate change policy. Bugnion is also an adjunct professor at Johns Hopkins University, where she teaches carbon finance and management. ■

Personnel Changes

John Parsons stepped down as the Joint Program's executive director to take on a larger role within the Sloan School of Management. He will remain the executive director of the Center for Energy and Environmental Policy Research (CEEPR) and continue his relationship with the Joint Program as a research collaborator.

Shubhada Kambli joined the program as assistant to the co-director for project management. She replaced Tony Smith Grieco, who left to work at a computer software company in California.

Sebastian Rausch (Project Director/USREP Model) left to take a position as a professor at ETH University in Zurich, Switzerland. The Joint Program looks forward to collaborating with him on future projects.

Justin Caron, a former visiting PhD student, was hired as a postdoc to work on economic research and the USREP model.

Henry Chen, a former postdoc who left to work at the World Bank, returned as a research scientist.

Eunjee Lee, a postdoc who studied the ecosystem and plant migration, took a position at Harvard University.

Zhang Da and **Tianyu Qi** are visiting students from Tsinghua University in Beijing working as part of the China Energy and Climate Project.

Alexandra Cosseron joined as a visiting student from Ecole Polytechnique in Paris, France from April to July.

Graduating students: Tanvir Madan, Cuicui Chen, Xiang Ling Yap, Megan Lickley, Paul Kishimoto, Arthur Gueneau.

Newly-Released Joint Program Reports

Report 226: The Economic, Energy, and GHG Emissions Impacts of Proposed 2017-2025 Vehicle Fuel Economy Standards in the United States

Report 225: Distributional and Efficiency Impacts of Clean and Renewable Energy Standards for Electricity

Report 224: Cap-and-Trade Climate Policies with Price-Regulated Industries: How Costly are Free Allowances?

Report 223: An Integrated Assessment Framework for Uncertainty Studies in Global and Regional Climate Change: The IGSM-CAM

Report 222: Modeling Water Withdrawal and Consumption for Electricity Generation in the United States

Report 221: Green Growth and the Efficient Use of Natural Resources

Report 220: Leakage from Sub-national Climate Initiatives: The Case of California

Report 219: Valuing Climate Impacts in Integrated Assessment Models: The MIT IGSM

Report 218: Permafrost, Lakes, and Climate-Warming Methane Feedback: What is the Worst We Can Expect?

Report 217: Combining a New Vehicle Fuel Economy Standard with a Cap-and-Trade Policy: Energy and Economic Impact in the United States

Report 216: Applying Engineering and Fleet Detail to Represent Passenger Vehicle Transport in a Computable General Equilibrium Model

Report 214: CliCrop: a Crop Water-Stress and Irrigation Demand Model for an Integrated Global Assessment Modeling Approach

Report 212: Effects of Nitrogen Limitation on Hydrological Processes in CLM4-CN

Forthcoming Joint Program Reports

IGSM-TEM Land use in CAM3.1-CLM3.0: Impacts of Land Use and Biofuels Policy on Climate

A global 3-D model to simulate long-range transport of polycyclic aromatic hydrocarbons: Evaluation and analysis

Multiple Adaptation Types with Mitigation: A Framework for Policy Analysis

Modeling Adaptation as a Flow and Stock Decision with Mitigation

Water-CO2 Tradeoffs in Electricity Generation Planning

The Future Energy and GHG Emissions Impact of Alternative Personal Transportation Pathways in China

Shale Gas Production: Potential Versus Actual GHG Emissions

Newly-Released Joint Program Reprints

Reprint 2012-14: The Impact Of Border Carbon Adjustments Under Alternative Producer Responses, Journal of Agricultural Economics

Reprint 2012-13: Emissions Pricing to Stabilize Global Climate, *Fiscal Policy to Mitigate Climate Change: A Guide for Policymakers, International Monetary Fund*

Reprint 2012-12: Development And Application Of Earth System Models, *Proceedings of the National Academy of Sciences*

Reprint 2012-11: Using Land to Mitigate Climate Change: Hitting the Target, Recognizing the Trade-offs, *Environmental Science and Technology*

Reprint 2012-10: Impact Of Aerosols On Convective Clouds And Precipitation, *Review of Geophysics*

Reprint 2012-9: Uncertainty Analysis Of Vegetation Distribution In The Northern High Latitudes During The 21St Century With A Dynamic Vegetation Model, *Ecology and Evolution*

Reprint 2012-8: Atmospheric Chemistry, Modeling, and Biogeochemistry of Mercury, *Mercury in the Environment: Pattern and Process*

Reprint 2012-7: The Weak Tie Between Natural Gas and Oil Prices, *The Energy Journal*

Peer-Review Studies/ Pending Reprints

Marginal abatement costs and marginal welfare costs for greenhouse gas emissions reductions: Results from the EPPA model, *Environmental & Resource Economics*

Changing the Climate Sensitivity of an Atmospheric General Circulation Model through Cloud Radiative Adjustment, *American Meteorological Society*

The Role of China in Mitigating Climate Change, *Energy Economics*

City-Size Distribution as a Function of Socioeconomic Conditions: An Eclectic Approach to Downscaling Global Population, *Urban Studies*

An Approximate Dynamic Programming Framework For Modeling Global Climate Policy Under Decision-Dependent Uncertainty, *Computational Management Science*

Joint Program In the News

http://globalchange.mit.edu/news-events/news

July 26, *New York Times,* Storms Threaten Ozone Layer Over U.S., Study Says

June 19, *Discovery News,* It's Not Just Summer, World Keeps Warming, June 19

June 4, *Inside Climate News*, Climate Scientists Lament a Nation Stuck on the Wrong Debate

May 31, *AP,* Warming gas levels hit 'troubling milestone'

May 23, *EnergyWire*, When -- if ever -- will the oil-gas price gap close?

March 27, *LA Times*, EPA emission standards may rule out new coal power plants

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