MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY of GLOBAL CHANGE

Global Changes

Fall 2013 | 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:

The State of Climate Assessments

As many of you know, the IPCC's Working Group 1 released their Fifth Assessment on climate change this fall. In it, they state plainly: "human influence on the climate system is clear" and "continued emissions of greenhouse gases will cause further warming and changes." Perhaps the strongest assertions from the IPCC to date, they certainly reflect the views of the Joint Program and the larger scientific community.

The team of IPCC scientists base their conclusions on observed changes, including: surface temperatures that have gotten successively warmer over the last three decades; rising ocean temperatures that have locked in more than 90 percent of the energy accumulated over the last four decades; retreating sea ice and snow cover and melting ice sheets; sea levels that have risen more since the mid-19th century than the average rate of the previous two millennia; and unprecedented levels of the dominant greenhouse gases carbon dioxide, methane and nitrous oxide. Simulations by climate centers around the world used by the IPCC display that one cannot attribute these changes to natural processes alone. In fact, the IPCC concludes that there's a 95 percent chance or greater that post–1960 warming is due to human influence—with the human influence, as measured by the global total radiative forcing (almost 1200 terawatts), being about 74 times current global human energy consumption.

What does this mean for our future? Under a medium climate sensitivity scenario, the IPCC projects that there's a 50 percent chance or more that by 2100 we'll exceed 2°C warming above the 1850–1900 average—the threshold that policy-makers often focus on to prevent catastrophic changes associated with climate change. This warming could cause: erratic changes to the global water cycle; a 90 percent chance or greater that the Arctic sea ice cover will continue to melt and that sea levels will continue to rise at a rate that's greater than that observed for the past four decades; and impacts to carbon cycle processes that will accelerate the rate of increase of carbon dioxide and methane in our atmosphere.

In comparing these assessments to our own, qualitatively they are generally similar. But where the IPCC simply poses future scenarios based on a range of emissions and resultant concentrations, at the Joint Program we're able to interweave technology development, economic costs and global trade and base our projections on specific policy choices. For example, in our 2013 Energy & Climate Outlook we use the Integrated Global System Modeling Framework (IGSM) to incorporate the emissions targets currently proposed in the Copenhagen-Cancun pledges. In doing so, we're able to base conclusions on concrete policies—leading us to find that total greenhouse gas emissions in 2100 will be almost 95 percent higher than 2010 emissions. We also go one step further, showing that by 2050 only 5 percent of the global electricity mix will be made up of renewable energy, and CO_2 emissions from electricity and transportation will grow by 46 percent and 60 percent respectively.

The integrated interdisciplinary approach we've been using in the Joint Program for the past 20 years is in stark contrast to the distinct disciplinary domains of the IPCC's three working groups. Recently, the global scientific community has begun to see the need to foster a more integrated approach akin to ours. In 2011, the U.S. National Academy of Sciences convened a group of scientists, including myself, to discuss the subject of integrated interdisciplinary climate science (http://www.pnas.org/cgi/collection/interdisciplinary_climate). Soon after, in 2012, the Royal Society (UK) also recognized the need and joined with the National Academy of Sciences to hold another symposium in which I also participated (http://royalsociety.org/policy/publications/2013/modeling-earths-future/). Hopefully, this growing consensus amongst the international community will soon also influence the basic setup of the IPCC.

Along with needing to better integrate the assessment process, some commentators have questioned the usefulness of the IPCC's reports in their current form. With their primary objective to advise the policymaking process, are they succeeding? I am not alone in my belief that they are not as effective as they should be. The six-year time intervals between reports are too long, the reports themselves are too large, and the messages from one report to another are structurally too similar. Because of these handicaps, the reports are missing valuable opportunities to better inform the global climate policy debate in a more timely and focused way.

For example, around the time of the release of the latest report, climate "deniers" pointed to the slowing of surface warming since 1998 as a reason to believe global warming is no longer occurring. But the informed scientific community is well aware that most of this "missing" heat is actually being stored in the oceans, with a possible influence also from volcanoes. At other times in the past, the oceans took up very little heat and thus accelerated the surface warming.

Many, including myself, believe it would be wiser to have short, more frequent specialized reports completed over a year's time that address new important issues. For example, a focused expert IPCC report on the roles of the oceans, volcanoes and solar cycles in adding variability to what would otherwise be a steady monotonic human-induced warming would have been very useful. Such focused studies would have far more impact because they would address the very issues that are affecting policy debates and decisions today.

As global, national and regional leaders confront climate change, it is our responsibility as climate scientists to provide them with the clearest, most timely and most comprehensive assessments possible. While the IPCC is a valuable institution, it could improve its structure and process to better equip political leaders to face the climate challenges of our time.

—Ronald Prinn

XXXVI MIT GLOBAL CHANGE FORUM
Coral Gables, FL, USA, January 29–31, 2013
Theme: Preparing for Climate Extremes

Evaluating the Risks of Natural Gas

MIT researchers weigh natural gas development options and economic risks for small nations using Cyprus as a case study.

As the U.S. and other large nations experience the benefits of a natural gas boom, smaller countries—from Tanzania to Cyprus—are hoping to reap the rewards too and use the resource to spur their economies. But in a new study, MIT researchers warn them to proceed with caution.

"While natural gas is often cheaper than oil and gives off fewer emissions, developing the resource comes with risks, especially for smaller nations," says Sergey Paltsev, an author of the study and a principal research scientist at the MIT Energy Initiative. "The cost for these smaller nations makes up a larger portion of their economies, so before spending the money, they need to have the proper expectations."

In collaboration with the Cyprus Institute, the MIT researchers take an independent look at the economics around developing the resource using Cyprus as an example. They find that it will take the country about five years to put their natural gas resource to use, and the required investments will make up to a quarter of the country's Gross Domestic Product (GDP).

"That's a substantial amount of a country's economy dependent on a resource that has proven to be unpredictable in the past," says Paltsev, who is also the assistant director for economic research at the MIT Joint Program on the Science and Policy of Global Change. "Natural gas development is so new to such regions, and the global gas market is changing so rapidly, that there's a large amount of uncertainty."

This is the message the researchers brought to a November meeting with Cyprus decision makers, meant to help the leaders plan a path forward with realistic expectations in mind.

The Case of Cyprus

What's happening in Cyprus is a good model for other countries like it that are exploring natural gas, according to Paltsev.

The small nation has been teetering back from a near collapse of its banking industry and searching for revenue. When a major natural gas reserve was discovered off its coast two years ago, Cyprus leaders saw it as a golden opportunity.

The latest estimate of the resource at that site, given earlier this month, shows about 5 trillion cubic feet of gas. To put that into context, the researchers cite a 2013 BP report showing the global supply of natural gas to be about 6,600 trillion cubic feet, with Russia's reserves alone being 1,160 trillion cubic feet.

"These numbers tell us that, while this is a significant find for a country the size of Cyprus, it's only a small fraction of the global resources," says Francis O'Sullivan, the director of research for the MIT Energy Initiative. "Most likely, Cyprus will never be a major player in the global gas markets, but that doesn't mean natural gas can't benefit the country's economy if developed properly."

One trillion cubic feet of natural gas is enough to meet the needs of 5 million households for 15 years, according to the American Gas Association. With the population of Cyprus being just around a million, the study shows that Cyprus has enough natural gas to power the country for nearly a century—while significantly reducing its use of foreign oil.

LNG versus a Pipeline

An ample resource for domestic use, the Cyprus government has made plans to build a Liquefied Natural Gas (LNG) plant and export the resource to such places as Europe and Israel.

LNG has been the preferred option over building a pipeline because of political tensions in the area. The island has been divided since the mid-1970s, with Turkey occupying the northern half.

While a clear political maneuver, building an LNG terminal would also create jobs and raise revenue. Depending on the tax scheme, it may raise $1.5 billion in taxes. Still, it would cost about $6 billion to build, for a country that has a GDP of about $25 billion. The cost of building an LNG terminal is far more than the cost of building a pipeline, though LNG offers greater flexibility to adjust production to changing natural gas prices and market supplies—perhaps outweighing the upfront costs.

"The discovery of natural gas has created exciting opportunities for Cyprus and could transform the country's energy system and position in the region," O'Sullivan says. "But the cost of developing the resource makes up about a quarter of the country's economy. That's not insignificant, and it's a major risk if it fails."

O'Sullivan and Paltsev warn that even projects that start out having clear economic gains can become less profitable because of poor technical planning and execution or bureaucratic and regulatory delays.

"Prices change, projects get delayed, overrun costs pile up. These are all unforeseen risks that can come up and must be properly mitigated," Paltsev says.

The study, funded entirely by the Cyprus Research Promotion Foundation, is part of a larger report that will further take into account the changing dynamics of the regional and global gas markets—giving a comprehensive view of the implications for the long-term development of natural gas in Cyprus and other like nations. The researchers expect to finish that larger report in August 2014. ■

Paltsev, S., F. O'Sullivan, N. Lee, A. Agarwal, M. Li, X. Li and N. Fylaktos, Natural Gas Monetization Pathways for Cyprus: Interim Report—Economics of Project Development Options, MIT Energy Initiative, 2013.

MIT SPOTLIGHT

A new MIT study by Christopher Knittel finds ethanol is not a major factor in reducing gas prices. Biofuels, contrary to claims, do not meaningfully affect what drivers pay at the pump. The study published in *The Energy Journal,* seeks to rebut the claim, broadly aired over the past couple of years, that widespread use of ethanol has reduced the wholesale cost of gasoline by $0.89 to $1.09 per gallon.

Read the news story: http://mitsha.re/1cDQx5T

Will the New Global Mercury Treaty Be Effective?

Noelle Selin assesses the challenges of implementing the first global mercury treaty.

After four years of negotiations, delegates from more than 140 countries met last January to finalize the first global treaty to mitigate and prevent mercury pollution, the Minamata Convention. Before delegates reconvened in October to sign the treaty, an MIT researcher analyzed its potential effectiveness.

"This is the first global treaty to tackle this major public health and environmental pollutant," says Noelle Selin, an assistant professor of engineering systems and atmospheric chemistry and a researcher with MIT's Joint Program on the Science and Policy of Global Change. "While the treaty may not be perfect, it's a step in the right direction."

Selin, who participated in the January meeting and attended the October signing, evaluated the impact of the treaty in a study published in the September issue of *Environmental Toxicology and Chemistry*. Her analysis finds that, once fully implemented, the greatest environmental benefits of the treaty will be from avoided increases in emissions.

The treaty addresses almost all mercury sources worldwide. But the actions required differ depending on the source of emissions, which include chemical and industrial processes such as the burning of fossil fuels, cement production, waste incineration and gold mining. For example, one provision of the treaty requires countries to devise national action plans to help limit and control artisanal and small-scale gold mining, one of the largest sources of mercury pollution at about 37 percent of emissions. Selin's assessment will help policymakers focus their attention on where they can make the most impact in reducing this harmful pollutant.

Selin calculates that once the treaty is fully implemented emissions will decrease slightly or stay at about today's levels. Because mercury takes decades to centuries to cycle through the environment, it will take a while before changes come into effect on a global scale. That explains why Selin's projections through 2050 show only a small decrease in environmental mercury levels, about 1–2 percent a year.

"Since mercury remains in the environment long after it is released, any decrease in mercury emissions will be slow to affect global mercury levels. This means that actions, or inactions, today will ultimately influence global levels long into the future," Selin says, stressing the significance of the treaty's progress, however limited.

"Without policy measures, mercury emissions are likely to increase dramatically and preventing these emissions today will benefit the environment in the long term. It's clear that

Anthropogenic Mercury Emissions to the Atmosphere and Associated Treaty Provisions

Category	Total budget (Mg) (Uncertainty range)	Covered by Minamata Convention	Convention requirements
Byproduct or unintentional emission			
Coal burning (all uses)	474 (304–678)	YES	Best available technology approach after 5–10 years
Oil and natural gas burning	9.9 (4.5–16.3)	NO	
Primary production of ferrous metals	45.5 (20.5–241)	NO	
Primary production of non-ferrous metals (Al, Cu, Pb, Zn)	193 (82–660)	YES (97%), except for Al	Best available technology approach after 5–10 years
Large-scale gold production	97.3 (0.7–247)	YES	Best available technology approach after 5–10 years
Cement production	173 (65.5–646)	YES	Best available technology approach after 5–10 years
Mine production of mercury	11.7 (6.9–17.8)	YES	Bans primary mining after 15 years
Oil refining	16 (7.3–26.4)	NO	
Contaminated sites	82.5 (70–95)	YES	Endeavour to develop strategies to identify, assess; cooperation
Intentional uses			
Artisanal and small-scale gold mining	727 (410–1040)	YES	Implement national plan
Chlor-alkali industry	28.4 (10.2–54.7)	YES	Phase-out by 2025
Consumer product waste	95.6 (23.7–330)	YES	Articles on products, wastes; incineration covered under point sources
Cremation (dental amalgam)	3.6 (0.9–11.9)	YES	Phase-down
Total emission	1960 (1010–4070)	1880 (96%)	

*Categories of atmospheric emissions are taken from UNEP and information from the Minamata Convention.

the Minamata Convention will help countries prevent future emissions," Selin says. "But we shouldn't expect an immediate change in mercury pollution levels."

Selin also notes that because the immediate drop in mercury levels over the next few decades is expected to be minor, "such a small decrease is less than we can confidently quantify using existing methods."

The treaty, however, does include provisions to enhance monitoring capabilities. Selin offers several suggestions in her analysis of how to best make these enhancements. For example, she encourages different measurement techniques for organic and inorganic forms of mercury since they behave in unique ways in the global environment. In addition, because much of the benefit of the treaty will involve avoided emissions, comparison between models that project future emissions will be critical.

"There are major gaps in researchers' ability to measure mercury pollution," Selin says. "The Minamata Convention works to address these gaps. I look forward to seeing increased monitoring and research as the treaty is implemented around the globe. It's a strong step, but must be just the first of many." ■

In October, Selin attended the signing in Japan and was part of an expert panel discussing the science and policies of mercury pollution, hosted by the National Institute of Minamata Disease and the Society of Environmental Toxicology and Chemistry.

Selin, N.E., Global change and mercury cycling: Challenges for implementing a global mercury treaty, *Environmental Toxicology and Chemistry,* in press, doi: 10.1002/etc.2374, 2013.

IN THE NEWS

Over the summer, Selin and students traveled aboard the specialized NCAR C-130 research aircraft as part of a mission to measure toxic air pollution.
More: http://mitsha.re/1aDZjyw

Study Finds the Hidden—and Uneven—Price of Piecemeal Energy Policies

MIT researchers compare sectoral policies to a price on greenhouse gases and discover both the national and regional impacts.

For more than three decades, policymakers have used a variety of regulations to reduce pollution and cut greenhouse gas emissions. Meanwhile, market-based policies like a carbon tax and cap-and-trade system have gained little traction. But are these piecemeal efforts costing us more money? Two MIT researchers say yes, after applying a United States regional modeling tool to assess them. Their findings will be published in an upcoming issue of *Energy Journal*.

"Often the efficient policies are not the most politically feasible," says Valerie Karplus, one of the authors and a research scientist at the MIT Joint Program on the Science and Policy of Global Change. "A cap-and-trade system limits carbon across the economy, incentivizing the cheapest reductions. Costs are also offset by the revenues from auctioned permits. We find by comparison that sectoral policies targeting efficiency or low-carbon technologies lead to high and—importantly—regionally localized costs."

Using the model, Karplus and her co-author Sebastian Rausch, formally at the MIT Joint Program and now a professor at ETH Zürich, compared the costs and effectiveness of traditional regulatory approaches to a cap-and-trade approach across different regions, sectors of the economy, and income classes through 2050.

The researchers found a striking difference between the cost of current clean electricity and vehicle policies and cap-and-trade policies that delivered the same overall reduction. This is because market-based systems allow for more flexibility in where emissions can be cut, spreading the costs across multiple sectors. Conversely, narrow regulations force cuts in the areas that are most costly and least effective in reducing emissions.

For example, fuel economy standards are typically politically attractive because they cut the amount of gasoline used—saving consumers money. But, Karplus says, the technology needed to make them more efficient can be expensive, raising the cost of the vehicles, and hiding the true price tag to consumers. Additionally, improved gas mileage encourages consumers to drive more because their fuel costs are lower, says Karplus. Under a cap-and-trade system, which would set a carbon price, these same consumers would have an incentive to conserve fuel.

"The cost effectiveness of policies is inherently linked to their flexibility," Karplus says. "With a broader policy, like cap-and-trade, the market can distribute the costs across sectors, technologies and time horizons, and find the cheapest solutions. So the market encourages emissions reductions from sectors like electricity and agriculture, and requires reductions from vehicles and electricity at a level that makes economic sense given an emissions target."

While significantly more expensive overall at the national level, Karplus and Rausch found that the piecemeal regulations also had adverse effects on specific regions and income groups.

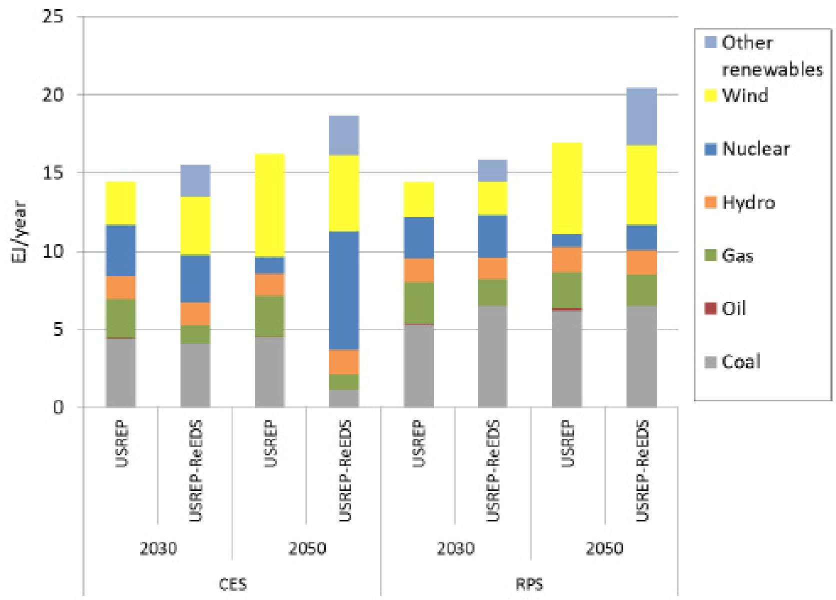
As an example, they tested the economic and welfare impacts of a renewable portfolio standard, which would require states to get a specific percentage of their power supply from renewable energy sources. They found that regions with dirtier grids and without access to wind resources, like the Mid-Atlantic, Great Lakes and Southeast, would see their electricity prices increase 100 percent by 2050. Meanwhile, regions that have already integrated renewable energy onto the grid—such as California, New York and New England—would be less affected by the standards and would see a limited welfare loss.

"This research clearly shows that regulatory policies can disproportionately affect some parts of the country over others," Karplus says. "But under a cap-and-trade system, we found that welfare impacts were more evenly distributed because reductions are spread across many sectors and regions, and focus on opportunities that make sense locally."

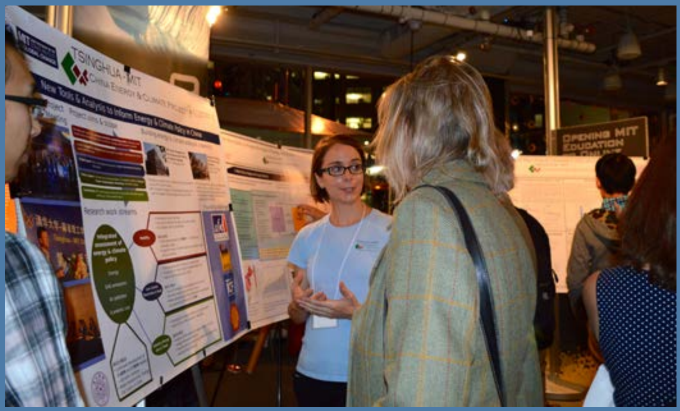
While the study suggests that a cap-and-trade system would come at a much lower cost, that hasn't been enough to pressure lawmakers to implement such a system.

"Even though a cap-and-trade system would cost less, the costs are very visible to businesses and consumers," Karplus says. "The higher price tag of the sectoral policies is also more concentrated and often goes unnoticed by the broader public. So unfortunately, the high costs of our current policies haven't been obvious enough to remove the political obstacles to implementing a more efficient approach." ■

Rausch, S. and V.J. Karplus, Comparing the U.S. Regional Impacts of Regulatory Standards to Cap-and-Trade, *Energy Economics*, in press, 2013.



Model comparison of U.S. electricity generation by fuel.



MIT ENERGY NIGHT

The CECP team presented their research at this year's Energy Night! The event is hosted annually at the MIT Museum and organized entirely by students. There were more than 70 interactive poster presentations from every energy–affiliated department at MIT.

El Niño Cycle Has a Big Effect on a Major Greenhouse Gas

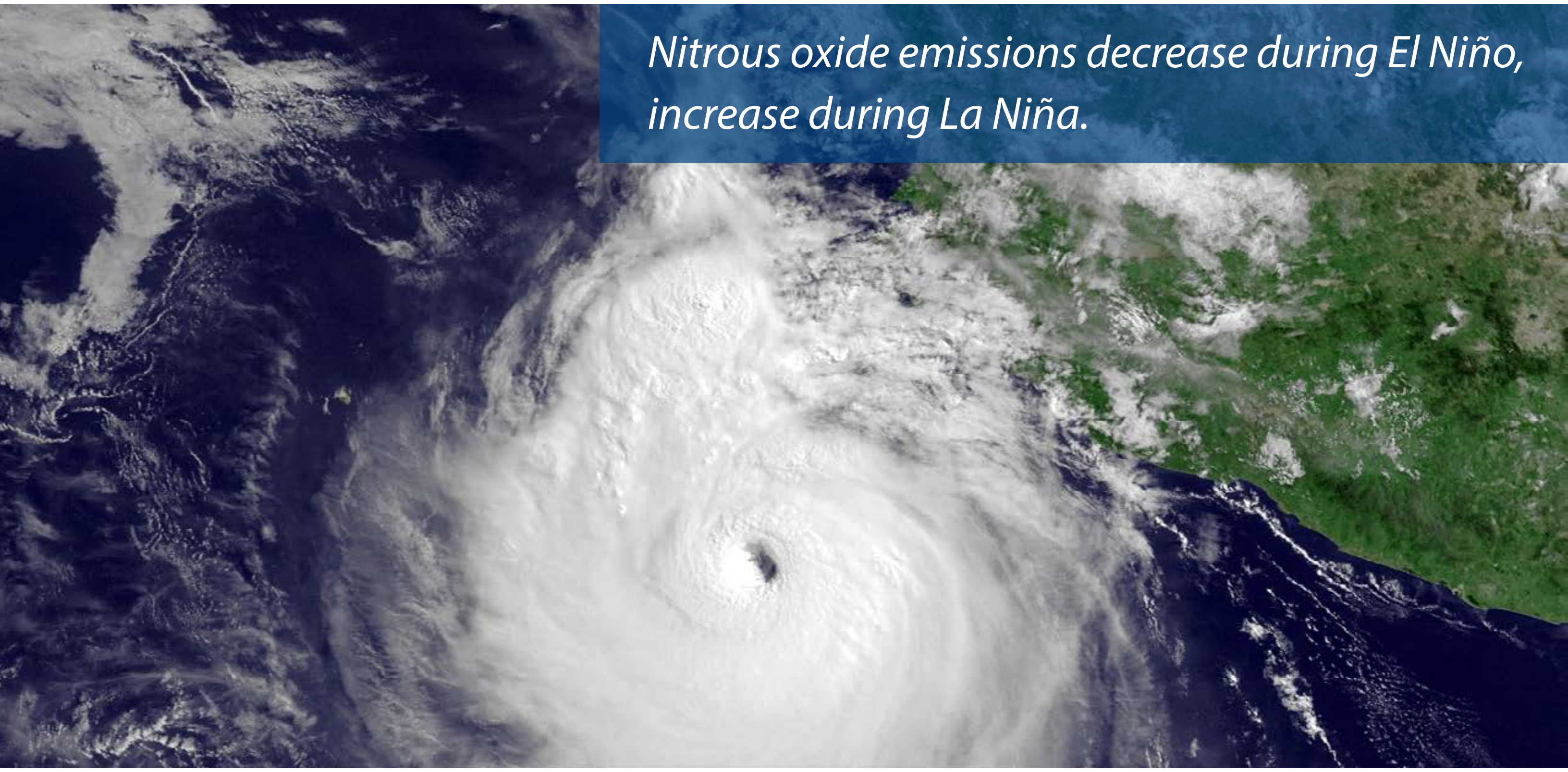
Jennifer Chu, MIT News Office

Nitrous oxide (N_2O) is commonly associated with laughing gas—the pleasantly benign vapor that puts patients at ease in the dentist's chair. But outside the dentist's office, the gas plays a serious role in the planet's warming climate.

After carbon dioxide and methane, nitrous oxide is the third-largest contributor of greenhouse-gas emissions to the atmosphere. The colorless gas is also the top culprit in the depletion of ozone—the layer of the atmosphere that protects Earth from the sun's ultraviolet radiation.

The majority of nitrous oxide emissions arise naturally from soil, where microbes break down nitrogen, releasing nitrous oxide as a byproduct. However, human activities such as farming, and the use of fertilizer, in particular, have increased nitrous oxide emissions over the last 35 years—a rise that has contributed to the overall warming of the planet.

Now scientists in MIT's Center for Global Change Science have developed a highly detailed model that simulates levels of nitrous oxide emissions in different regions and ecosystems of the world. Based on local soil temperature and moisture content, some of the simulations were able to reproduce actual nitrous oxide measurements. From their simulations, the researchers discovered a surprising pattern: Regions around the world typically experience a decrease in nitrous oxide emissions during El Niño events, which periodically create unusually warm waters in the Pacific Ocean, affecting temperature and rainfall patterns around the world. Conversely, they found that emissions rise during periods of La Niña, the opposing weather pattern, in which colder waters take over the Pacific. The findings suggest a feedback mechanism in which nitrous oxide not only contributes to global warming, but may also be affected by climate patterns.



"If more emissions are released into the atmosphere, there will be more global warming […] and with higher temperatures, we would have more nitrous oxide coming out," says Eri Saikawa, who led the research as a postdoc at MIT. "Many people may not consider the nitrogen cycle, but we do have to realize it is pretty important."

Saikawa, who is now an assistant professor of environmental studies at Emory University, collaborated with Ronald Prinn, the TEPCO Professor of Atmospheric Science at MIT and director of the Center for Global Change Science, as well as principle research scientist Adam Schlosser. The group has published its results in the journal *Global Biogeochemical Cycles*.

A Seesaw of Emissions

To simulate nitrous oxide emissions around the world, Saikawa adapted a model of soil temperature and moisture content that is often used by hydrologists to track the movement of water through soil.

Saikawa added to this model a component that calculates how much nitrous oxide is likely emitted from a region, given variables such as soil temperature and moisture. She simulated monthly global nitrous oxide emissions from 1975 to 2008; to check that the model generated accurate calculations, Saikawa simulated nitrous oxide emissions in regions where actual nitrous oxide measurements were available, including 25 locations in the Amazon, North and Central America, Asia, Africa and Europe.

For many of the sites, the model's calculations agreed with observations, verifying its ability to accurately simulate nitrous oxide emissions. Looking at the variability of emissions from year to year, Saikawa noticed a dramatic correlation with the El Niño/La Niña climate pattern, particularly in tropical regions near the equator: Nitrous oxide emissions dipped during periods of El Niño, and spiked during La Niña events.

Saikawa says this periodic seesaw in emissions makes sense: As El Niño warms the Pacific, rainfall increases to the east, causing flooding in parts of South America, and droughts in parts of south Asia. Saikawa points out that the largest sources of nitrous oxide emissions arise from south Asia; Saikawa observed that decreased soil moisture from El Niño led to a large dip in emissions from those regions, with the opposite effect from La Niña.

"We thought we would see some variability, but we didn't think it would be this significant," Saikawa says. "There is a need for more research to really determine what are the possible impacts from future climate change."

William Horwath, a professor of soil biogeochemistry at the University of California at Davis, says the group's model, while relatively simple, generally does a good job of predicting nitrous oxide events. However, to truly dig down to the root cause of emissions, he says the model will have to incorporate many more factors, including the presence of iron, which Horwath says is a big player in regulating microbes and nitrous oxide emissions.

"Future modeling studies stand to gain valuable information by considering iron among the regional drivers of N_2O emission," Horwath says.

Modeling Better Fertilizer

Going forward, the team will incorporate agricultural components into the model, to simulate the effect of certain fertilizers on nitrous oxide emissions. Many types of fertilizer introduce nitrogen to the soil—an ingredient that nitrogen bacteria thrive upon. The more fertilizer nitrogen there is in soil, the more bacteria break it down, releasing nitrous oxide as a byproduct.

Prinn says that deforestation has also stirred up nitrous oxide emissions, particularly in regions such as Brazil. The Brazilian government, he says, is exploring the increased production of biofuels, fertilizing croplands in place of forests.

"Brazil and other countries are very concerned about the sustainable production of biofuels in the future," Prinn says. "What damage will it do to soil health? […] Will they be making biofuels that are causing nitrous oxide and carbon dioxide emissions?"

A model like Saikawa's, he says, may help simulate the effect of biofuel production on nitrous oxide emissions, and present more sustainable methods for growing biofuel crops.

"We should think about the impact that we have from our agricultural activities," Saikawa says. "Over-fertilizing our soil could be potentially quite damaging for the climate and also for the ozone." ■

Saikawa, E., C.A. Schlosser and R.G. Prinn, Global modeling of soil N_2O emissions from natural processes, *Global Biogeochemical Cycles,* 27(3):972–989, 2013.

IN THE NEWS

Stephanie Dutkiewicz talks to *Scientific American* about how changes in phytoplankton populations could greatly impact the oceans. Learn more: http://mitsha.re/1aEfJqy

China Energy and Climate Project

The Unintended Benefits of Pollution Rules

MIT researchers find China's new SO_2 and NO_x regulations will also reduce CO_2 emissions.

China's unprecedented economic growth has created a more affluent society that demands more energy. The current growth is leading to more emissions from power plants and industries, which threaten human health, the economy and the environment. Government officials recognize the severity of the problem and have taken action through a series of policy initiatives in the 12th Five-Year Plan (2010–2015).

"Power plants, factories and vehicles have all increased sulfur dioxide (SO_2) and nitrogen oxide (NO_x) pollution, which cause smog and acid rain and lead to health effects such as heart disease, asthma and shortened lifespans," says Kyung-Min Nam, a researcher in MIT's Joint Program on the Science and Policy of Global Change. "The increased stringency of new pollution controls reflects a growing recognition of the public health, economic and environmental costs of air pollution in China."

SO_2 and NO_x are byproducts of the burning of fossil fuels and other activities that cause CO_2 emissions, so limiting these pollutants can also reduce CO_2 emissions.

Nam and his colleagues wanted to research effective ways for policymakers to reduce air pollution and mitigate carbon emissions, given the potential interactive effects of these policies.

In a study published in the November issue of *Global Environmental Change*, they evaluated the unintended CO_2 emissions reductions in the new SO_2 and NO_x regulations in China's 12th Five-Year Plan. They found that the tighter SO_2 and NO_x regulations would reduce CO_2 enough to allow China to surpass its 2015 goals—by a substantial margin.

"It is clear that the unintended benefits of the regulations are substantial and would allow the government to improve air quality, while also cutting the most potent greenhouse gas. We have also learned that carbon emissions may not rise as high as some forecasts suggest, if concerns about conventional pollutants lead to air pollution reduction policies," Nam says.

In the 12th Five-Year Plan, the Chinese government committed to reduce SO_2 emissions by 8 percent and NO_x emissions by 10 percent from 2010 levels. In addition, the government established a target to reduce CO_2 intensity by 17 percent from the 2010 level. The researchers found that by 2015 the SO_2 and NO_x regulations could reduce CO_2 intensity by 20 percent, exceeding China's official goal.

Valerie Karplus, a co-author of the study and the director of the MIT Joint Program's China Energy and Climate Project, says, "Considering that the current CO_2 target can be attained by the secondary benefits of the SO_2 and NO_x regulations, policymakers would do well to coordinate the regulatory efforts. Currently, they have room to adopt more ambitious CO_2 reduction policies, but the impact will hinge on effective implementation."

The researchers also estimate that the regulations have the potential to save the Chinese economy $3 billion, the estimated costs of compliance with the CO_2 intensity targets.

"We find that China can meet its short-term pollution goals and still expand the use of coal. However, continued use of coal will ultimately make future emissions reductions excessively expensive. The government can achieve greater cost savings for industry by choosing policies that require earlier action and investment in long-term reduction goals," Nam says. "This emphasizes the need for a forward-looking approach that anticipates more significant reductions in the future and includes cleaner technologies in the near term."

Nam plans to continue this research by extending the modeling to the U.S. He will compare the unintended benefits of both pollution and climate regulations in China and the U.S. and quantify the interactive effects in both directions. ■

Nam, K., C. Waugh, S. Paltsev, J.M. Reilly and V.J. Karplus, Carbon co-benefits of tighter SO_2 and NO_x regulations in China, *Global Environmental Change*, in press, 2013.

IN THE NEWS

Valerie Karplus talks to *ClimateWire* about Da Zhang's latest research on quantifying the benefits of a national emissions trading system in China. Learn more: http://mitsha.re/184WTIB and read the study http://mitsha.re/184WYfr

COMMENTARY

Transforming China's Grid, *The Energy Collective*

Michael Davidson, a doctoral student with the China Energy and Climate Project, critically examines China's efforts to reinvent and decarbonize its power sector and other energy goals. He wrote four pieces as part of a new *Energy Collective* column: "East Winds, with Michael Davidson."

Sustaining the Renewable Energy Push
http://mitsha.re/19YQoqC

Integrating Wind Energy Before It Blows Away
http://mitsha.re/19YQkqC

Will Coal Remain King in China's Energy Mix?
http://mitsha.re/19YQnTs

Obstacles on the Path to a National Carbon Trading System
http://mitsha.re/19YQvlO

Feeding the World without Consuming the Planet

MIT researchers and industry experts address global resource challenges and ways to confront them.

Global population is expected to rise from about 7 billion today to close to 11 billion by the end of the century. This growing population will increase the demand for food, putting further strain on global land and water resources already feeling the pressures of climate change. Responding to the urgency of these challenges, the MIT Joint Program on the Science and Policy of Global Change brought together experts from academia and industry at a food symposium on November 5th, "Feeding the World without Consuming the Planet."

MIT Vice President Claude Canizares joined Joint Program on Global Change Co-Director Ron Prinn in opening the event. He highlighted MIT's dedication to expanding research on agriculture, as urged by President Obama's Council of Advisors on Science and Technology in a report published last December. He also emphasized the Institute's long history of forming industry collaborations to confront the world's greatest challenges.

"MIT's 150-year history of being devoted to the industrial arts makes us very comfortable to work closely and in real partnership with industry. I can't think of a more important problem for us to tackle," said Canizares at the event, which included experts from Cargill, Coca-Cola Co., Mosaic Company, Weyerhaeuser Company and Bunge Limited.

Cargill Vice Chairman Paul Conway also gave opening remarks outlining the challenges of increased food consumption, accelerating urbanization, demands for biofuels and variability in climate.

"We see climate change as a critical risk. We have to prepare ourselves to make sure we adapt," said Conway, who also encouraged additional research in science and technology.

"To ignore some tools that are available to us that have had a significant impact—particularly in terms of the reduction of chemicals—would be foolish."

Agricultural Resources and Inputs

Joint Program Co-Director John Reilly kicked off the first session of the event with an overview of MIT's work on modeling water stress, resource demands, variability in temperature and precipitation patterns, and the economic impacts of climate change on food prices.

"We need to better understand local and regional climate changes and extremes to improve agriculture," said Reilly, of which the Joint Program is already studying with their Integrated Global System Model (IGSM)—a tool that connects Earth and human systems to better predict future climate changes.

Industry is also doing its part to maximize yields and adapt to climate change. Reilly's session focused on two key industries in particular: forestry and fertilizers.

As fertilizer companies meet growing productivity demands, they must focus on improving resource inefficiencies and misallocations of fertilizer in the developing world, said Michael Rahm of the Mosaic Company. Meanwhile, timberlands management could help mitigate climate change, according to Robert Ewing of the Weyerhaeuser Company. Weyerhaeuser is also working with Chevron to research how timber scraps could be used in biofuel production.

Agricultural Commodity Markets, Food and Consumers

The second session of the event progressed up the food production chain and looked at the impacts on prices and trade.

Describing the challenge of growing food prices, Professor Thomas Hertel from Purdue University said that there are many factors to watch including biofuel expansion, oil prices, technical capabilities, drops in research and development, and climate change. Hertel also explained income rises in the developing world will encourage diets to change and require more land intensive agriculture. Improved efficiency in trade and technology will be essential in meeting the demands of growing affluent societies.

Stewart Lindsey of Bunge Limited agreed with the importance of trade. "It plays a very important role in the world," he said. "It really is a mechanism that gives deficit countries—countries that don't have enough food to ensure security—the ability to do that in a pinch."

Only 15 percent of global grains and oilseeds are exported today. By expanding global trade of agriculture, Lindsey

The 2013 Food Symposium speakers and moderators

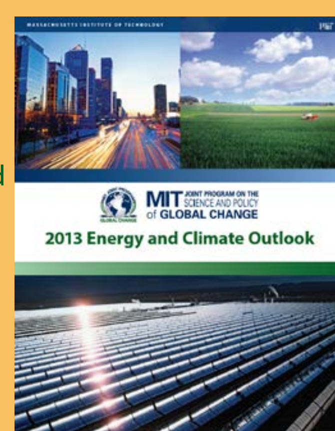
suggested we should urge countries to be more efficient by growing and exporting foods based on their locally available resources and climate conditions.

As the food and agriculture industry continues to prepare for climate change and increased food demands by supporting agricultural trading, optimized yields and sustainable agricultural practices, Reilly emphasized the important role of academia in such efforts during his closing remarks.

"We look forward to continuing this conversation with collaborators in industry," Reilly said, "in order to improve our understanding of all these challenges, and find the best ways to adapt to our changing climate and resource demands." ■

Watch videos from the event and read about our coverage on social media at http://globalchange.mit.edu/foodsymposium

2013 ENERGY & CLIMATE OUTLOOK



The 2013 Energy and Climate Outlook provides an integrated assessment of how human activities, given our current development path, are interacting with complex Earth systems and ultimately affecting the natural resources on which we depend.

Learn more: http://globalchange.mit.edu/Outlook2013

AGAGE Celebrates 35 Years of Atmospheric Observations

For decades, climate scientists around the globe have worked together to document and measure the composition of the Earth's atmosphere. This group, the Advanced Global Atmospheric Gases Experiment (AGAGE), met in October in Boston for their biannual meeting and to celebrate their 35th anniversary.

"Over the past 35 years, this international consortium of researchers has furthered our understanding of a large number of important global chemical and climatic phenomena," says Ronald Prinn, the TEPCO Professor of Atmospheric Science and leader of AGAGE. Prinn is also co-director of the Joint Program on the Science and Policy of Global Change.

They gather this data 20 to 30 times per day at nine coastal or mountain measurement stations located in the U.S., Ireland, Norway, Switzerland, China, South Korea, Tasmania, Barbados and American Samoa. There are also two collaborative stations in Italy and Japan. Members of AGAGE have produced hundreds of articles related to measurement techniques, trends of gases in the atmosphere, air circulation patterns, and more. For example, in 2008, AGAGE scientists were the first to report the renewed rise in methane concentrations beginning in 2006. Methane is the second most important long-lived greenhouse gas that contributes to climate change. Just a month ago, using data collected from AGAGE, *Nature Geoscience* published a study documenting three decades of global methane observations and emissions.

"The vital data we collected through AGAGE enabled us to better understand the many sources and sinks of methane and their remarkable variability," says Prinn, a co-author of the study. The collaborating scientists from Europe, the U.S. and other countries concluded that the post-2006 rise is likely because of increased fossil fuel emissions and natural emissions from wetlands. While the exact contributions of these sources are still uncertain, this new research creates a clearer picture of trends in methane emissions around the globe.

Methane is just one of over 50 important long-lived atmospheric gases AGAGE researchers study that affect the ozone layer, climate change and air pollution.

Each station in this global observation network uses the same fully automated on-site instrumentation and calibration scales, so data can be easily compared and aggregated. The stations are strategically distributed throughout the globe to capture both hemispheres, and both polluted and less polluted regions. Beyond methane, the stations capture the majority of purely man-made greenhouse gases, such as hydrofluorocarbons (HFCs) from refrigerators and air conditioners, sulfur hexafluoride from electrical distribution grids, and hydrochlorofluorocarbons (HCFCs), that are also one of the remaining rising pollutants known to deplete the ozone layer. Monitoring efforts like AGAGE help policymakers measure the effectiveness of pollution regulations.

Supported primarily by NASA, the data produced by the AGAGE network is available publicly through the U.S. Department of Energy greenhouse gas archive, and is used to support the implementation of international agreements like the Montreal and Kyoto protocols.

"AGAGE provides essential data to researchers around the globe and allows us to continue to better understand the chemistry of the Earth's atmosphere and the human forcing of climate change," Prinn says. "We are looking forward to seeing what the next 35 years of AGAGE will bring." ■

Joint Program Computing Cluster Goes Green

The Joint Program on the Science and Policy of Global Change's work centers on a series of models that require expansive, heavy-duty computing equipment. The MIT Integrated Global System Modeling framework (IGSM) and its component features—the Emissions Prediction and Policy Analysis (EPPA) model, MIT General Circulation Model (MITgcm), Community Land Model (CLM)—and others—all rely on a shared computer cluster. For many years, this cluster was housed in a special room on campus, but this summer the Joint Program made a change.

"We simply outgrew the room," says Jeffery Scott, a research scientist with the Joint Program. "There was no more space, no more power and no more cooling capacity."

These challenges put the program's computing equipment at risk, and led to frequent power and cooling failures—challenges for the more than 80 students, postdocs and research staff who rely on the cluster for their work. But this summer, the Joint Program moved the cluster to a bigger, greener facility in Holyoke, Massachusetts, the Massachusetts Green High Performance Computing Center (MGHPCH).

The MGHPCH is a collaboration between Boston University, Harvard, MIT, University of Massachusetts, Northeastern University and the Commonwealth of Massachusetts.

The move allows the Joint Program to expand its computing capabilities and utilize the new facility's hydroelectric power. Additionally, the MGHPCH facility is LEED Platinum certified by the U.S. Green Building Council for a series of energy and water efficient features—including a cooling system that uses outdoor air, an efficient high-voltage power system, and hot aisle containment to reduce the cooling needs of computers.

"Now, the program can continue to expand its computing capabilities and will never have to worry about outages, power requirements and cooling needs, says Scott, who administers the computing cluster and facilitated the move. "Flexibility and operational support at the Holyoke facility will also enable us to continually upgrade and augment our current hardware." ■

INTEGRATED GLOBAL SYSTEM MODEL (IGSM)

The IGSM analyzes interactions among humans and the climate system. More: http://globalchange.mit.edu/research/IGSM

The Politics of Public Opinion

Straight out of Williams College with a bachelor's degree in economics, Christopher Warshaw landed a job studying the costs and benefits of environmental rules at a consulting firm in Cambridge, Massachusetts. What he learned there would forever change the course of his career and his outlook.

"What struck me during that work is it generally wasn't the cost and benefit analysis driving environmental policy decisions, it was aspects of the political process," Warshaw said. He had planned to go back to school to complete his environmental economics training. "But through my experience at the consulting firm, I decided that wasn't really where we needed progress. Instead, it was important for me to understand more about how the political system works in order to do research that could positively change the world."

Specifically, Warshaw was driven by the issue of climate change.

"Climate change is this enormously important challenge," Warshaw says. "How we should confront that challenge and what our energy mix should look like to address it—while also enabling the economy to keep going and enabling people to have affordable power—is complicated. I think good people can disagree on the details, but it's just enormously important for our society to face up to this challenge."

After working a couple years on political campaigns—further providing him with context on how the system works in order to tackle that challenge—Warshaw went to Stanford for his PhD in political science. Now an assistant professor at MIT, Warshaw continues to ask: What is it that causes us to end up with the types of policies we have? How well do those policies represent what the public wants? And, to be effective citizens, how can we make a difference?

What he's found in his research has been stark, though perhaps not surprising.

"One of the theories that interest groups operate under is that if they can change public opinion on an issue, then that eventually should drive legislators or elected officials to take action," Warshaw says.

Do our opinions matter? Political scientist Christopher Warshaw is working to find out, as he uncovers the impact of public opinion on the policy process and strategies to create environmental change.

"It turns out that it takes vast shifts in public opinion—with about 80 percent of the public supporting a position—to motivate legislators to vote against their partisan priorities."

Warshaw gives an example. In 2008, when Congress voted to bail out the auto industry, conservative Michigan Republicans voted for it because the vast majority of the public in Michigan—largely made up of auto workers and their families—supported it.

Warshaw has seen similar results at the local level, and drilled down to see if different institutions—direct democracy, term limits, city managers versus elected officials, etc.—make governments more responsive to public opinion. While unfortunate, he found such institutions didn't seem to make much difference.

Next, Warshaw is working to draw a connection between public opinion and roll call votes at the state level. One of the motivations for this work is that "there are a lot of great environmental and energy policies that one could do at the local level," Warshaw says.

One of the first state policy areas he plans to explore is renewable energy policy. But to do this, he needs data, and at the state and local level there are virtually no surveys of public opinion on environment and energy. So he's running the original surveys himself—starting with opinions on renewable energy, but later he plans to expand to other topics like hydraulic fracturing.

"One would expect that because a state like Wyoming depends so heavily on the coal industry the people from that state would be very pro coal. But we don't actually know if that's the case because nobody's ever asked," Warshaw says. "This is information we need to stop assuming we know."

Once Warshaw has data on public opinion, he'll compare that to the data he and his graduate student are collecting on roll call votes in state legislatures.

"This will help us figure out if public opinion actually matters at that level because if you're a state legislator it's not obvious you would even know what the public opinion is," Warshaw says.

He explains that this is important information to know not just because legislators should take public opinion into account when voting, but also because if you're trying to persuade people to change their minds by knocking on doors and running ads, making calls, etc. "In the end, if the legislator doesn't know that the public's mind has been changed it doesn't matter," he says.

Warshaw doesn't pretend to have all the answers, but he does want to find out how the political process works and how it can be influenced in part to pass this knowledge on to his students, who collectively someday could have the answers.

"The students here are brilliant. They're going to go out and try to find solutions to real problems. It's just part of the engineering mindset," Warshaw says. "But we also need to make sure they understand the complexities and nuances of environmental and energy policy."

That means, according to Warshaw, making sure they understand more than just their small part. They need to understand the big picture and how other aspects of the process influence their work.

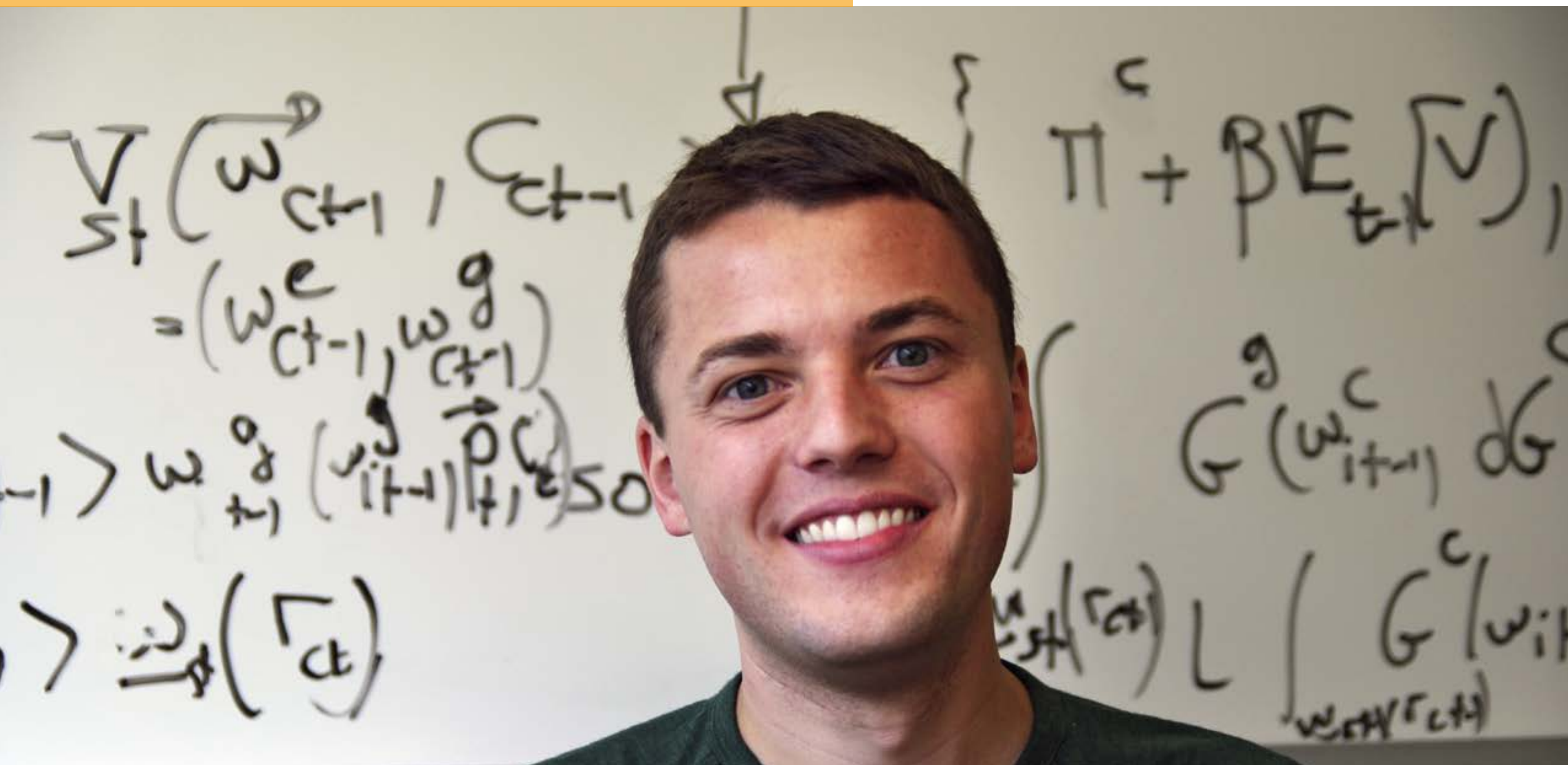
"It's really important for students to be exposed to a wide variety of the liberal arts and different perspectives," Warshaw says. "If we give them the right training, my experience is that smart people can rise fast and I believe they can really make a difference in the world very quickly." ■

MIT SPOTLIGHT

A new MIT study by Michael Greenstone reduces pollution in India while calling conventional auditing markets into question. Through an eye-opening experiment involving roughly 500 industrial plants in the state of Gujarat, in western India, researchers find that when an auditing firm's revenues come directly from its clients, auditors have an incentive not to deliver bad news. This research was published in the *Quarterly Journal of Economics* in October.

Learn more: http://mitsha.re/160awIo

Student Spotlights



Michael McClellan: Understanding the Mysteries of the Earth's Atmosphere

Growing up in Independence, Missouri, Michael McClellan experienced many hot and humid summer days. As a kid, he used to take a can of bug spray and twirl it around, spray it in a great ribbon, and see it catch the light.

"Now, as a chemist, I can look back on that and say 'wow,' I was putting a lot of stuff into the atmosphere—I really shouldn't have," says McClellan, a new PhD student with Ronald Prinn, co-director for the Joint Program and the TEPCO Professor of Atmospheric Science. "Those experiences as a kid led to my interest in studying indoor consumer products and their effects on the atmosphere."

Michael McClellan joins the Joint Program as a doctoral student with Ron Prinn.

As an undergrad at Carleton College, McClellan became a chemistry major. For an environmental analysis class, he developed a hypothetical research project where he would investigate the effects of indoor air fresheners. This class project ultimately turned into a two-year research project that allowed McClellan to further expand his knowledge of the impacts of aerosols on human health and the environment.

"I really enjoy doing applied research that can have an impact on people's daily lives," says McClellan.

Now, as a doctoral student, he plans to continue researching problems that affect human health by working with the Advanced Global Atmospheric Gases Experiment (AGAGE) Network, led by Prinn.

McClellan will have the opportunity to visit some of the AGAGE stations to better understand the different components of the atmosphere and then use the high-resolution data in models to understand how air is travelling, where pollution comes from, and who will be affected.

"I want to do my best to tease out the different mysteries of the Earth's atmosphere and add more details to the larger picture of climate change, human health and the way that the air travels around the globe."

"I want to do my best to tease out the different mysteries of the Earth's atmosphere and add more details to the larger picture of climate change, human health and the way that the air travels around the globe," explains McClellan "I think that just by learning more fundamentally about the air that everyone breathes we can begin to have some really practical applications for policy decisions."

McClellan was drawn to MIT, the Joint Program, and Prinn's research group in the Earth, Atmospheric and Planetary Sciences (EAPS) Department because of the broad group of researchers and the opportunity to study a wide range of topics—meteorology, chemistry, policy and human health—all together.

"I am just completely overjoyed that I can bring together all of these fundamental interests I've had for a long time," says McClellan. ■

From left: Eric Hittinger, the USAEE case competition coordinator, poses with MIT students Michael Craig, Michael Davidson and Ashwini Bharatkumar.

MIT STUDENTS TAKE FIRST-PLACE AWARD

Four MIT students won first place in a competition by the U.S. Association of Energy Economics (USAEE) aimed at tackling today's energy challenges and preparing solutions for policymakers and industry. The students, Ashwini Bharatkumar, Michael Craig, Daniel Cross-Call and Michael Davidson, competed against teams from other North American universities to develop a business model for a fictitious utility company in California facing uncertain electricity growth from a rise in electric vehicle charging.

With the goal of minimizing distribution system upgrade costs, the MIT team tested how well several business models or technology alternatives could address the utility company's challenge. These included: implementing a real-time pricing and demand response program, using battery storage, using controlled charging or some combination of the three. Learn more here: http://mitsha.re/19YPf24

Jennifer Morris: Hedging Bets to Minimize Future Energy Costs

When Jennifer Morris came to MIT for her masters in the Technology and Policy program (TPP), she never intended to stay on to complete a doctorate. Six years and two degrees later, Morris doesn't plan to leave any time soon.

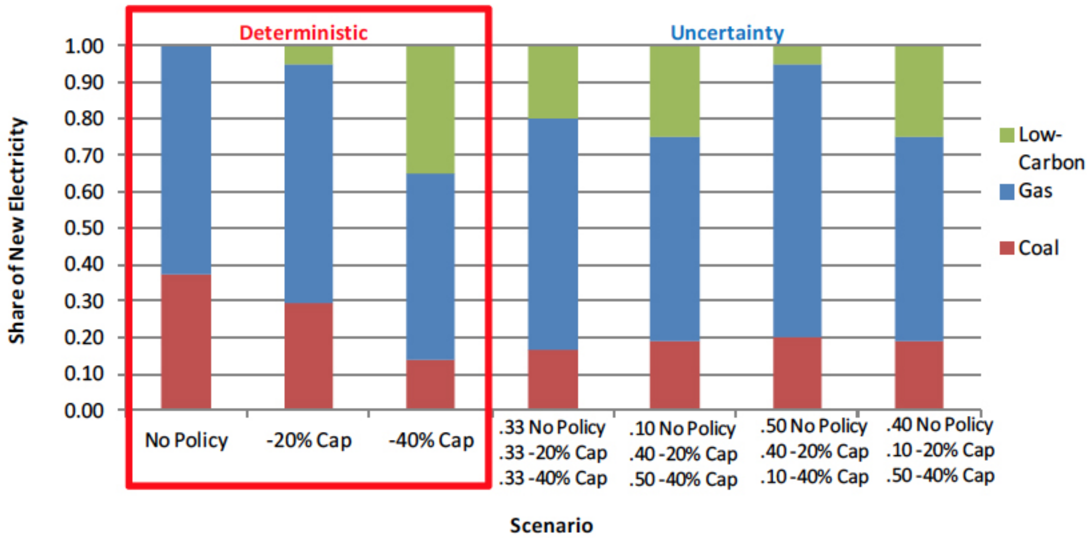
"I was originally drawn to TPP because of the interdisciplinary approach to solving energy and technology challenges. I learned how to understand, analyze and assess complex public policy problems and then evaluate and create solutions," says Morris. "Once I was here, I fell in love with MIT and the work I was doing and haven't wanted to leave since."

Morris began her new role as a research scientist at the Joint Program this fall.

A self-proclaimed "nature lover" and public policy buff, Morris put her two passions to work as a masters student at MIT studying the impact of energy systems on the environment. Working with John Reilly, co-director of the Joint Program, and Sergey Paltsev, the assistant director for economic research, Morris studied the impacts of combining a cap-and-trade policy with a renewable portfolio standard.

"At the time, a number of climate proposals were being considered by Congress. Through the Joint Program, I had the opportunity to produce some analysis of the bills," Morris says. "It was exciting to see our work actually being used by legislators to help make decisions."

When Morris finished her master's program, she felt there was still a lot she wanted to learn, so she decided to stay on to complete a PhD in MIT's engineering systems division.



Stage 1 Shares of New Electricity under Policy Uncertainty. Morris, J., *Doctoral Thesis,* May 2013.

"The research I conducted for my master's provided great insights on how policies effect and impact each other," Morris says. "But there was one area that stuck out as something that could be improved upon—the representation of uncertainty in our models."

Specifically, Morris wanted to help policymakers, utilities and energy companies make near-term decisions about the electricity mix while taking into account uncertainty about the future.

"I wanted to know what should we be building in the next 10 to 15 years, given that we don't know what future policy will be and how much different technologies will cost," she says.

To tackle these two major uncertainties—future policies and future technology costs—Morris built a model and used a two-step process to help decision makers. First, she ran the model based on current information of energy policies, technologies and costs. She then ran the model under a series of possible future scenarios, each assigned a probability. After determining the optimal future scenario, she worked backwards to analyze what current electricity investments placed the decision maker in the best possible position to achieve the optimal future outcome.

Morris found that when uncertainty is taken into account in the decision making process, the optimal near-term electricity investment decisions are distinctly different from research that does not include this kind of uncertainty. Because the electricity plants and technologies that are built today will be in place for many years to come, identifying near-term decisions that hedge against future uncertainties allows investors to better plan for the future and minimize energy and policy costs.

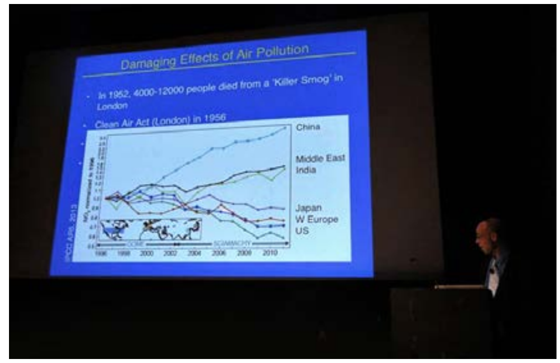
"The actions that occur today affect the probabilities of how things will unfold in the future," says Morris. "The more information about future policies and costs we incorporate into our decision making, the better utilities and companies can hedge their bets in the face of uncertainty."

During her time with the Joint Program, Morris learned how to develop solutions and tackle important policy questions from an interdisciplinary approach—something she looks forward to continuing in her new position.

"At the Joint Program, economists and scientists learn to speak each other's language and work together," says Morris. "It's a unique group, even within an institute like MIT." ■

The Environment @ MIT

13th Annual Henry W. Kendall Memorial Lecture: "How Air Pollution Affects Climate and What We Can Do About It"



This year's Kendall Lecturer Drew Shindell, a senior scientist at the NASA Goddard Institute for Space Studies in New York City, discussed recent progress in understanding the role of aerosols and ozone and the implications for our understanding of climate sensitivity. He also explained that taking action to reduce air pollutant emissions has benefits to both the climate and human health. The Henry W. Kendall Memorial Lecture Series honors the memory of Professor Henry Kendall (1926–1999), a 1990 Nobel Laureate, a longtime member of MIT's physics faculty, and an ardent environmentalist.
More: **http://mitsha.re/17tr5mc**

3rd Annual Carlson Lecture: Sea Ice, Climate and Observational Mathematics with John Wettlaufer

To better understand Earth's climate, we seek theories that predict observations regionally and globally, from human to geologic time scales. But what are the relevant observations? And how do we construct useful and realistic theories? Offering his reflections on these and other questions, Professor John Wettlaufer, Yale University, was the keynote speaker at the Lorenz Center's third annual John Carlson Lecture on Thursday evening, October 10, 2013. The John Carlson Lecture Series, generously funded by MIT alumnus John Carlson, aims to communicate new results in climate science to the general public.
More: **http://mitsha.re/17trCVn**

2013 EPPA RETREAT TRAINING

On October 4th–6th, the Joint Program held its annual Emissions Prediction and Policy Analysis (EPPA) Model training workshop. About 25 students, staff and sponsors attended the workshop. The primary purpose was to introduce new research assistants to the economic modeling approach and software. Co-director John Reilly and MIT researchers Niven Winchester, Jennifer Morris and Henry Chen presented a series of sessions including the basics of a computable equilibrium (CGE) model, how to construct a simple model from scratch, orientation and application of the Joint Program's EPPA model, and stochastic dynamic programming.

Read the short news story on the event, learn about what sponsors gained from the experience, and watch videos of all of the training sessions at: **http://globalchange.mit.edu/sponsors-only/EPPA**

Geoengineering: Science & Governance

Sponsored by the MIT Joint Program and the Harvard University Center for the Environment

Debating the Future of Solar Geoengineering

On August 7th, Oliver Morton from the *Economist* moderated a panel discussion on the future of solar geoengineering with Stephen Gardiner of University of Washington, David Keith of Harvard University, Alan Robock of Rutgers University and Daniel Schrag of Harvard University. The panelists discussed the potential of geoengineering technologies, the social and physical risks and the challenges of international agreement on the subject. The event was hosted at MIT. More: **http://mitsha.re/1ffi4gc**

Debating Climate Geoengineering

On October 28th, Steven Barrett, assistant professor of aeronautics and astronautics at MIT, moderated a panel discussion with David Keith of Harvard University and Clive Hamilton of Charles Sturt University in Australia. The panelists discussed the challenges of geoengineering and how this technology could and should be managed. More: **http://mitsha.re/1ffiJhJ**

Women in Clean Energy Symposium

On September 19th and 20th, MIT and the U.S. Department of Energy held the second annual Women in Clean Energy Symposium. The goal was to provide women in clean energy with a range of perspectives, analysis and data on clean energy challenges, and a forum for informal networking. Women in the clean energy sector recieved awards for their work, in addition to a series of panel discussions and poster presentations. Rebecca Saari, a PhD student with the Joint Program, presented a poster on the air quality co-benefits of clean energy and climate change policies. More: **http://mitsha.re/1ffkSdl**

Climate CoLab: Crowds and Climate Conference

On November 6–8th, the MIT Joint Program on the Science and Policy of Global Change, MIT Energy Initiative, the MIT Center for Collective Intelligence and MIT Sloan School of Management sponsored a two-day program to explore the role that new technology-enabled approaches—such as crowdsourcing, social media and big data—can play in developing creative new ideas and taking action on climate change. John Reilly, Jake Jacoby and Valerie Karplus all presented on panels to discuss the research of the Joint Program. More. **http://mitsha.re/1hGvVRm**

SPONSORS EXCLUSIVE

XXXVI (36th) MIT Global Change Forum
January 29–31, 2014, Coral Gables, Florida USA

Theme: *Preparing for Climate Extremes*

Individual Sessions will address the following topics:

- Coastal Infrastructure & Severe Tropical Storms
- Floods and Droughts
- Arctic & Energy Vulnerability
- Health, Heat Waves & Air Pollution
- Preparation for COP 2015: U.S. and China
- Panel session: The Outlook for COP 2015

By invitation only.
Please contact Frances Goldstein at fkg@mit.edu

Assessing the Terrestrial and Atmospheric Nitrogen Cycle

Project Leaders: Adam Schlosser (MIT), Eri Saikawa (Emory University, Lead)

Despite nitrous oxide (N_2O) being a major ozone (O_3) depleting species and greenhouse gas, its sources and emission rates are not well understood. There are large uncertainties in soil emissions, both from natural processes and fertilizer use, as well as discrepancies in ocean emissions. Improved understanding of N_2O emission processes over the surface of the globe is needed to accurately quantify past, present, and future impacts on stratospheric O_3 and climate. We address these issues by using an interdisciplinary approach that integrates observations (from NOAA, the Advanced Global Atmospheric Gases Experiment, and other networks) and bottom-up as well as top-down modeling. Using the N_2O emissions obtained from the process model combined with N_2O observations, we will refine our estimate of global and regional annual N_2O emissions for 5 different sources over the last 15 years with MIT's Integrated Global System Model (IGSM)-CAM3 Model.

Incorporating a variety of projections simulated in the MIT IGSM, we will assess the impact of potential future climate on soil N_2O emissions, and how potential future land use change and the extent of anthropogenic combustion-related activities may affect these emissions. We will explore the response of terrestrial biogeochemical systems, assess various mitigation pathways, and calculate current and possible future stratospheric ozone loss due to the predicted N_2O emissions. Overall, this project will enhance our understanding of the impact of N_2O emissions not only on the nitrogen cycle, but also on climate and on stratospheric O_3.

Source: National Oceanic and Atmospheric Administration

Coupled Natural & Human Systems: Managing Impacts of Global Transport of Atmosphere-Surface Exchangeable Pollutants in the Context of Global Change

Project Leaders: Noelle Selin (MIT) and Judith Perlinger (Michigan Tech, Lead)

This project focuses on how toxic pollutants travel through the environment to affect human and ecosystem well-being. The toxic pollutants examined in this project are air pollutants that can be stored in land and water at the Earth's surface, then rereleased to the atmosphere (which we term here Atmosphere-Surface Exchangeable Pollutants or ASEPs). These pollutants travel in and interact in the environment at multiple scales, and interact with human activities, through governance and regulation as well as social dimensions of human exposure and risk. In this project, we will simulate the global transport of ASEPS to estimate land–atmosphere exchange under different future climate and land–use scenarios. We will then quantify the economic costs in the United States of exposure to these chemicals, and will analyze efforts to manage the chemicals at scales ranging from local to global, with a geographical focus on the Laurentian Great Lakes.

The study will examine details about the environmental cycling of these pollutants that currently impede our ability to model their global transport and fate and thus inform policy decision making. The project will also assess the economic damages caused by these pollutants in the United States. Public outreach and distributed K–college education activities, and partnering between researchers, educators, stakeholders, and decision makers will promote incorporation of research results into learning, education and governance. This project brings together a diverse group of natural and social scientists from four academic institutions to study the problem of pollutants in a more holistic fashion than has ever been attempted to date, and may serve as a model for studying other classes of substance in the future.

Source: U.S. National Science Foundation

Coming and Going

Joshua Hodge was hired as deputy executive director for resource development and will be replacing **Loren Cox** when he retires in December.

Robert Morris was hired to replace **Tony Tran** as administrative assistant for the Joint Program.

Xiaohu Luo is a visiting PhD student from Tsinghua University.

Yichen Du, Corey Tucker, Danwei Zhang and **Jiakun Zhao** are all pursuing masters degrees in the Technology and Policy Program and have been hired as research assistants.

Zhanna Kapsalyamova joined the program as a Fullbright Visiting Scholar from the Economic Research Institute in Astana, Kazakhstan.

Newly-Released Joint Program Reports

Report 253: An Analogue Approach to Identify Extreme Precipitation Events: Evaluation and Application to CMIP5 Climate Models in the United States

Report 252: Synergy between Pollution and Carbon Emissions Control: Comparing China and the U.S.

Report 251: Regulatory Control of Vehicle and Power Plant Emissions: How Effective and at What Cost?

Report 250: The Association of Large-Scale Climate Variability and Teleconnections on Wind Energy Resource over Europe and its Intermittency

Report 249: Limited Sectoral Trading between the EU ETS and China

Report 248: The Energy and Economic Impacts of Expanding International Emissions Trading

Newly-Released Joint Program Reprints

Reprint 2013-26: Modeling Water Resource Systems within the Framework of the MIT Integrated Global System Model: IGSM-WRS

Reprint 2013-25: Toward evaluating the effect of climate change on investments in the water resources sector: insights from the forecast and analysis of hydrological indicators in developing countries

Reprint 2013-24: Quantifying regional economic impacts of CO_2 intensity targets in China

Reprint 2013-23: Probabilistic projections of 21st century climate change over Northern Eurasia

Reprint 2013-22: Is Small Better? A Comparison of the Effect of Large and Small Dams on Cropland Productivity in South Africa

Reprint 2013-21: A stochastic minimum principle and an adaptive pathwise algorithm for stochastic optimal control

Reprint 2013-20: Policy Diffusion of Emission Standards: Is There a Race to the Top?

Reprint 2013-19: Economic impacts of climate change on water resources in the coterminous United States

Reprint 2013-18: Off-line algorithm for calculation of vertical tracer transport in the troposphere due to deep convection

Reprint 2013-17: A Numerical Investigation of the Potential for Negative Emissions Leakage

Reprint 2013-16: Response of evapotranspiration and water availability to changing climate and land cover on the Mongolian Plateau during the 21st century

Reprint 2013-15: Winners and losers: Ecological and biogeochemical changes in a warming ocean

Reprint 2013-14: Land–Ocean Warming Contrast over a Wide Range of Climates: Convective Quasi-Equilibrium Theory and Idealized Simulations

Reprint 2013-13: Nuclear exit, the US energy mix, and carbon dioxide emissions

Reprint 2013-12: Re-evaluation of the lifetimes of the major CFCs and CH_3CCl_2 using atmospheric trends

Reprint 2013-11: Future trends in environmental mercury concentrations: implications for prevention strategies

Reprint 2013-10: Permafrost degradation and methane: low risk of biogeochemical climate-warming feedback

Peer-Review Studies/ Pending Reprints

Costs of reducing GHG emissions in Brazil, *Climate Policy*

Integrated Economic and Climate Projections for Impact Assessment, *Climatic Change*

Estimating global black carbon emissions using a top-down Kalman filter approach, *Journal of Geophysical Research—Atmospheres*

Global modeling of soil nitrous oxide emissions from natural processes, *Global Biogeochemical Cycles*

Climate Co-benefits of Tighter SO_2 and NO_x Regulations in China, *Global Environmental Change*

Global Change and Mercury Cycling: Challenges for Implementing a Global Mercury Treaty, *Environmental Toxicology and Chemistry*

Responses in global soil consumption of atmospheric methane due to changes in atmospheric climate, methane concentration, and nitrogen deposition, *Global Biogeochemical Cycles*

Beyond 2020—Strategies and costs for transforming the European energy system, *Climate Change Economics*

Influence of tropical tropopause layer cooling on Atlantic hurricane activity, *Journal of Climate*

Water consumption footprint and land requirements of large-scale alternative diesel and jet fuel production, *Environmental Science & Technology*

Joint Program In the News

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

October 28, *Christian Science Monitor,* How global warming could boost green energy in an unexpected way (+video)

October 24, *Chemistry,* Global treaty on mercury emissions signed

October 23, *Cyprus Mail,* Evaluating the risks of natural gas

October 13, *Financial Times,* Report questions auditors' ethics

October 1, *Bloomberg,* Climate Change Rescue in U.S. Makes Steyer Converge With Paulson

September 27, *Tech Review,* New IPCC Report Strengthens Certainty of Climate Change

September 27, *Discovery,* The IPCC Climate Report: What Good Will It Do?

September 26, *NBC News,* Final verdict coming on Friday: Humans caused global warming

September 16, *Nature News,* Study revises estimate of methane leaks from US gas fields

September 13, *New York Times,* E.P.A. Is Expected to Set Limits on Greenhouse Gas Emissions by New Power Plants

September 1, *Times of India,* Air pollution causes 200,000 early deaths each year in US

August 19, *Economist,* How safe is fracking?

August 8*, Scientitifc American,* Sweeping Change in Phytoplankton Populations Could Remake Oceans

August 5, *Bloomberg,* How Cleaning China's Dirty Air Can Slow Climate Change

August 3, *New York Times,* Life in a Toxic Country

July 24, *Washington Post,* Did the Clean Air Act unleash Atlantic hurricanes?

MIT Joint Program Sponsors

The work of the Joint Program is funded by an international partnership of government, industry, and foundation sponsors, and by private donations. Our sponsor consortium provides the long-term substantial commitment needed to support our dedicated and specialized staff, and to realize a coordinated integrated research effort.

Alstom Power (USA)
American Electric Power (USA)
BP (UK)
Cargill (USA)
Caterpillar (USA)
Centro Mario Molina (Mexico)
Chevron (USA)
CLP Holdings (Hong Kong)
ConocoPhillips (USA)
Deutsche Asset Management (USA)
Dow Chemical (USA)
Duke Energy (USA)
Electric Power Research Institute (USA)
Electricité de France (France)
Eni (Italy)
Exelon (USA)
ExxonMobil (USA)
GDF SUEZ (France/Belgium)
J-Power (Japan)
Lockheed Martin (USA)
Murphy Oil (USA)
Norwegian Ministry of Petroleum and Energy (Norway)
Oglethorpe Power Corporation (USA)
Petrobras-Petroleo Brasilerio S.A. (Brazil)
RWE Power (Germany)
Shell International Petroleum (Netherlands/UK)
Southern Company (USA)
Statoil (Norway)
Suncor Energy (Canada)
Tokyo Electric Power Company (Japan)
Total (France)
Toyota Motor North America (USA)
Vetlesen Foundation (USA)
U.S. Department of Agriculture [USDA]
U.S. Department of Energy [DOE]
U.S. Department of Transportation [DOT]
U.S. Environmental Protection Agency [EPA]
U.S. Federal Aviation Administration [FAA]
U.S. National Aeronautics and Space Administration [NASA]
U.S. National Science Foundation [NSF]

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY of GLOBAL CHANGE

Copyright © 2013
MIT Joint Program on the
Science and Policy of Global Change
77 Massachusetts Avenue, E19-411
Cambridge, MA 02139 USA

E-mail: globalchange@mit.edu
Phone: (+1) 617.253.7492
Fax: (+1) 617.253.9845

For inquiries, permission to reproduce material, or to subscribe to future newsletters, please email: globalchange@mit.edu

Global Changes is published triannually by the MIT Joint Program on the Science and Policy of Global Change, explicitly for our program membership. It reports on research results and news/events around the Joint Program. All articles are written by Vicki Ekstrom, Alli Gold Roberts and Audrey Resutek, unless otherwise noted.

MIT