MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY of GLOBAL CHANGE

# Global Changes

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## 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

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# Observations on the State of Climate Policy Around the World

Even as negotiators work to make progress on mitigation efforts during the annual U.N. climate talks, growing evidence that the climate is changing has brought necessary attention to adaptation. But in both cases, mitigation and adaptation, I think we can gain more insight — and optimism — from studying what is happening on the ground in countries, cities and companies, than from reading tea leaves of what might happen with ongoing talks.

While I am hardly the first or only observer to have long seen lack of leadership from the U.S. as a stumbling block to international progress, at least one lingering question has been answered: President Obama will remain in office for four more years and the U.S. Congress will remain divided. With that question answered, many remain.

Though it seems the U.S. has done nothing on climate change because there is no broad-based policy, piecemeal regulations, state actions and the unforeseen fortune of shale gas development have allowed emissions to decline. However, we only have to look back to the decline of emissions in Europe in the 1990's — caused by a recession, "dash to gas" and the shutting down of Eastern Europe's inefficient coal plants — to be reminded that the U.S. decline may not be permanent. If we have any hope of significantly reducing emissions in an economically-efficient manner, some form of broad-based carbon pricing will be needed. Is that politically possible?

That answer could come straight out of the gate, as Washington turns its attention to the looming debt crisis early next year. After hearing little to nothing on climate change during the campaign, the President addressed the issue in his first press conference: "If…we can shape an agenda that says we can create jobs, advance growth, and make a serious dent in climate change and be an international leader, I think that's something that the American people would support." A carbon tax would do that and more.

As many of you now know, we've studied this approach. Our analysis has found that a carbon tax, starting at $20 per ton, could raise $1.5 trillion over the next decade, while cutting emissions by more than 20 percent by 2050. This could be part of an even broader based tax reform that the Republican House is calling for, and the revenue raised could be one part of a solution to the deficit crisis facing the country.

With countless questions still left unanswered in the U.S., a main reason for optimism on climate mitigation is that many countries are moving ahead without U.S. leadership. Our expanding work in China, and more broadly Asia, suggests some reason for hope there. Mainland China's 12th 5-year plan has ambitious goals for reducing conventional pollutants — $NO_X$ and $SO_X$ — and if those goals are achieved it would likely have a significant impact on $CO_2$ emissions as well. China is also actively testing a cap-and-trade system that could expand nationally starting in 2015. However, the issue in China is a confusing array of policies and uncertainty about how they will interact, and whether and how they will be enforced. Our challenge from a research perspective is to sort out the efficient and effective policies among these.

Elsewhere, Taiwan and Korea are actively setting up cap-and-trade systems with ambitious emissions reduction targets. Battling the fall-out from the Fukushima nuclear disaster, Japan announced recently they would begin a carbon-offset credit system with several Asian nations next April, perhaps boosting the flagging credit market. In October, Australia issued its first carbon credits under a new trading scheme — despite threats from the opposition party that they would discontinue the measure if elected next year. Brazil, which has succeeded in reducing emissions from deforestation in recent years, continues on its path despite a measure last spring that weakened efforts. Mexico, too, has ambitious plans.

There is still a long way to go, and much of this "progress" is in the form of plans rather than actions. But they are plans taken up by governments that have the power to act, rather than international agreements that have either slowly withered or were dead on arrival when brought home.

On the adaptation side, we hear much progress from you, our industrial sponsors. Whether it is crop-breeding plans, storm preparedness, water management, or energy-water conflicts, the changing climate overlays the challenges posed by meeting the needs of a growing population, increasing demands, and conventional resource management challenges. Cities, too, are at the forefront of thinking about adaptation, as we saw when Hurricane Sandy devastated coastal New York and New Jersey.

It is easy to ignore mitigation, leaving that to others, but if we fail to adapt our cities and businesses we cannot escape the consequences. While our mitigation studies continue strongly, our Program is turning much attention toward the difficult problem of adapting to a highly uncertain climate future (see more on that in the following pages). With your continued support, we hope to contribute to the understanding of many of these issues over the next year and beyond.

— John Reilly

**XXXV MIT Global Change Forum**
Cambridge, MA, USA, June 4-6, 2013
Proposed Theme: Food and Water

# New Method Could Help Communities Plan for Climate Risk

*MIT researchers develop tool to assess regional risks of climate change, potential impacts on local infrastructure and planning.*

Climate scientists cannot attribute any single weather event — whether a drought, wildfire or extreme storm — to climate change. But extreme events, such as Hurricane Sandy, are glimpses of the types of occurrences the world could be more vulnerable to in the future. As the devastation left by Sandy continues to reverberate, decision-makers at every level are asking: How can we be better prepared?

MIT researchers have developed a new tool to help policymakers, city planners and others see the possible local effects of climate change. Its regional projections of climate trends — such as long-term temperature and precipitation changes — allow local planners to evaluate risks, and how these risks could shape crops, roads and energy infrastructure.

"As we see more extreme events like Sandy, the importance of assessing regional impacts grows," says lead researcher Adam Schlosser, assistant director for science research at MIT's Joint Program on the Science and Policy of Global Change. "Our approach helps decision- and policy-makers balance the risks … so they can better prepare their communities for future impacts climate change might bring."

For example, Schlosser says, if a community is planning to build a bridge, it should look at — and plan for — the expected magnitude of flooding in 2050.

"In areas devastated by Sandy, the rebuilding of lost property and infrastructure will come at considerable cost and effort," Schlosser says. "But should we rebuild to better prepare for future storms like these? Or should we prepare for stronger and/or more frequent storms? There remains considerable uncertainty in these projections and that implies risk. Our technique has been developed with these questions in mind."

Schlosser's research partner, Ken Strzepek, a research scientist at the Joint Program on the Science and Policy of Global Change, notes policymakers are now often given little more than a set of extreme circumstances to consider.

"Policymakers don't like extremes or worst-case scenarios," Strzepek says, "because they can't afford to plan for the worst-case scenarios. They like to see what is the likelihood of different outcomes. That's what we're giving them."

### Getting Results

In this new method, the researchers quantify the likelihood of particular outcomes and add socioeconomic data, different emission levels and varying degrees of uncertainty. Their technique combines climate-model projections and analysis from the Coupled Model Intercomparison Project used by the Intergovernmental Panel on Climate Change, and the MIT Integrated Global System Modeling (IGSM) framework. The MIT framework is itself a combined computer model that integrates an economic, human system with a natural, earth system.

"This approach allows us to widen the scope and flexibility of climate analysis," Schlosser says. "It provides us with efficient capabilities to determine climate-change risks."

The initial study using this approach — accepted by the *Journal of Climate* and available on the journal's website — compares a business-as-usual case with a scenario that reduces emissions. The researchers find that lowering emissions reduces the odds of regional warming and precipitation changes. In fact, for many places, the likelihood of the most extreme warming from the business-as-usual case could be eliminated almost entirely.

The study finds diverse climate-change outcomes: southern and western Africa, the Himalayan region, and the area around Hudson Bay in Canada are expected to warm the most; southern Africa and western Europe see the greatest chance of drier conditions. Meanwhile, the Amazon and northern Siberia may become wetter.

### Putting the Method to Work

Schlosser and Strzepek are pursuing partnerships with communities to put their method to work. But while it's important for every community to begin building climate adaptation into its infrastructure plans, developing countries could reap the greatest benefits.

Malcolm Smart, senior economic adviser for the U.K. Department for International Development, who was not involved in this research, says, "This is not only an innovative and multidisciplinary approach to the problem of deep uncertainty, but also a potentially very valuable tool to help vulnerable developing countries cut the cost of damages from climate change."

Strzepek explains why: In the United States, infrastructure plans are designed based on a high standard of risk, while in developing countries projects are typically built to a lower standard of risk. "But if we find that [a developing country] will see greater flooding, and if we're fairly certain of this, then they would save money in the long run if they built roads to withstand those flooding events," Strzepek says.

Schlosser and Strzepek traveled to Finland earlier this fall to present their research at a United Nations University-World Institute for Development Economics Research conference. They've partnered with this organization to inform developing countries of this new tool for assessing climate change.

"Our approach allows decision-makers to cut down on the level of risk they're taking when allocating their limited funds to development projects," Schlosser says. "This can help them see where there are economic benefits to taking a risk-averse approach today, before the damage is done." ■

Schlosser, C.A., X. Gao, K. Strzepek, A. Sokolov, C.E. Forest, S. Awadalla and W. Farmer, Quantifying the Likelihood of Regional Climate Change: A Hybridized Approach, *Journal of Climate*.

### SPONSOR EXCLUSIVE

On December 12, Adam Schlosser, Ken Strzepek and Élodie Blanc will hold a webinar on "Impacts of Human and Environmental Change on Regional and Global Water Resources." Learn more: http://globalchange.mit.edu/sponsors-only/webinar

# Vehicle Efficiency Standards vs. A Carbon Tax: The Costs and Politics

*MIT researchers show the merits of a carbon tax.*

New standards to strengthen vehicle fuel efficiency are considered one of the landmark environmental achievements of President Obama's first term. Passed with the backing of automakers and autoworkers, the measure has been touted as a way to save consumers more than $1.7 trillion at the pump and cut carbon emissions from passenger vehicles in half. While the standards have many good merits, a more effective approach might be an economy-wide carbon tax, say researchers at MIT's Joint Program on the Science and Policy of Global Change.

The researchers look at the full energy and economic impacts of the efficiency standards, which in their finalized form now require automakers to install pollution-control technology to improve the fuel efficiency of cars by 5 percent and light trucks by 3.5 percent with each new model year starting in 2017. Published this month in the journal *Transportation Research Record*, the study won this year's Pyke Johnson Award for the best paper in the area of planning and the environment.

"Common thinking in Washington holds that any policy that seems to advance technology without creating new taxes must be a no brainer for the country. That misses the broader economic impact," says Joint Program Research Scientist Valerie Karplus, the lead author of the study. "As my colleague says, you may see more money in your front pocket at the pump, but you're financing the policy out of your back pocket through your tax dollars and at the point of your vehicle purchase."

Instead, Karplus says a gasoline or carbon tax makes more sense economically by providing consumers a direct incentive to either reduce their driving or buy more efficient vehicles.

"From an economic perspective that's very clear, but from a political feasibility perspective it's very different," she says. Unlike fuel standards that hide the true costs, "a tax on gasoline has proven to be a nonstarter for many decades in the U.S., and I think one of the reasons is that it would be very visible to consumers every time they go to fill up their cars."

The one hope, Karplus and some of her colleagues at the Joint Program say, is that in the midst of deficit talks a tax on carbon emissions might be considered to help raise the money needed to slash the deficit and avoid some tax hikes and spending cuts. The program published a study in August that looked at the effectiveness of this approach. That study showed that with a carbon tax the economy could improve overall, other taxes could be lowered, and pollution emissions would be reduced.

"Congress will face many difficult tradeoffs in stimulating the economy and job growth while reducing the deficit," says John Reilly, the co-director of the Joint Program and an author of the carbon tax study. "But with the carbon tax there are virtually no serious tradeoffs."

Conversely, when Karplus and her colleagues simulated the proposed fuel economy standards, they found that while drivers of these more efficient vehicles will likely save at the pump, they could on average spend several thousands of dollars more when buying their new car, consistent with EPA estimates. Even more troubling, diverting efforts toward improved vehicle efficiency distorts overall economic activity, adding to the indirect cost of the policy.

Estimates of how costly the policy would be — in terms of both direct costs to consumers and the larger rippling costs to the economy — hinge on the relative cost of the technology and other strategies available to improve efficiency. The shorter the time frame automakers have to develop the technology and produce more efficient vehicles, the less time there will be for technological progress and other factors to drive down costs — such as the cost of batteries — and the more consumers will need to pay upfront. Emissions and oil imports will initially drop, both due to increased fuel efficiency and as the higher vehicle costs weigh on consumer budgets. But as consumers face lower costs per mile traveled, they may drive more, offsetting reductions in emissions and oil imports.

Karplus hopes her results will help policymakers make more informed decisions going forward. She credits that to the innovative — and award-winning — method she used, which weaves engineering and technology constraints into a broad economic framework and allows researchers to test the cost and other impacts of a policy at different levels of stringency. This method inherently takes account of life-cycle emissions as well as impacts that transmit across fuel markets by affecting prices.

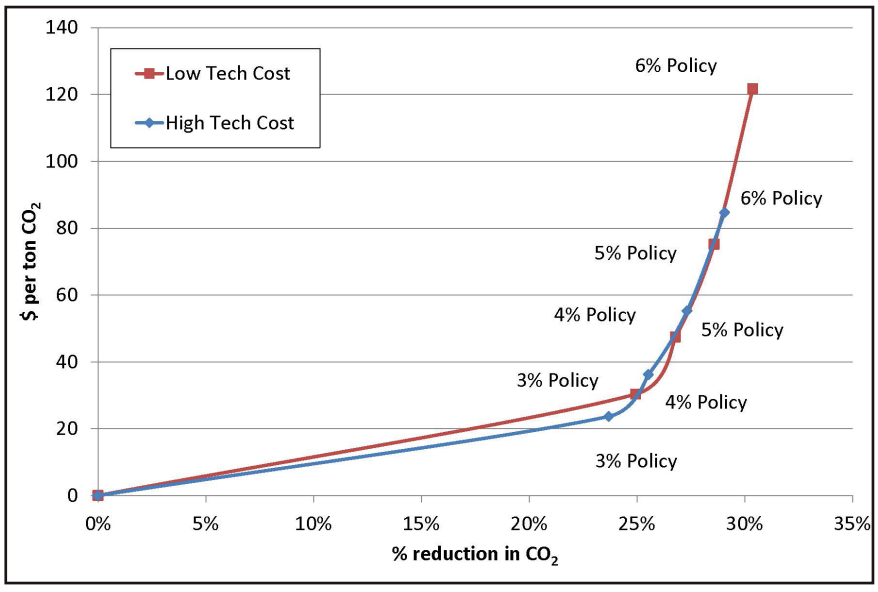
For example, a policy might only consider gasoline use by plug-in electric hybrids. But that "tailpipe measure" doesn't take into account the emissions created from building, transporting and recharging those batteries. Her approach does.

"There are a lot of hidden costs to a policy like this," Karplus says. "This model doesn't allow you to ignore other important aspects of the economy and energy systems. It requires you to be explicit about your technology and cost assumptions. It provides a framework that allows lawmakers to look at all the available information on costs and the state of the technology and decide how to best create or update policies."

Of this approach, University of Maine environmental economist Jonathan Rubin, says "The research of Dr. Karplus on the energy and climate impacts of the nation's fuel economy standards for our cars and trucks makes an important contribution to policymaking based on science."

Rubin is the chair of the Transportation Energy Committee of the Transportation Research Board, which will honor Karplus with the Pyke Johnson award at a ceremony in January. ■

Karplus, V. and S. Paltsev, The Economic, Energy, and GHG Emissions Impacts of Proposed 2017-2025 Vehicle Fuel Economy Standards in the United States, *Transportation Research Record*, 2012.




**Average cost in 2025 of $CO_2$ emissions reductions under varying levels of fuel economy standard stringency relative to a business as usual case.**

**Award Winner!**
Valerie Karplus received the Pyke Johnson Award for the best paper in the area of planning and the environment for this study.

# Study Maps Pollution's Path to the Arctic, Sets Path for Future Research

*MIT researchers have built a model that will be further developed as part of an NSF-funded project to track how chemicals get to remote Arctic environments.*

It's been more than a decade since global leaders met in Stockholm, Sweden, to sign a treaty with the goal of eliminating persistent organic pollutants making their way into our food chain — such as harmful pesticides like DDT that nearly wiped out the American Bald Eagle. While leaders have come a long way in restricting these types of pollutants, contamination of the Arctic remains a problem. Researchers at MIT are working to help inform policies that more effectively address contamination problems with their latest research and the help of a new grant from the National Science Foundation.

"Persistent organic pollutants are chemicals of substantial international concern," Noelle Selin, the project's lead researcher and assistant professor in MIT's Engineering Systems Division and Department of Earth, Atmospheric and Planetary Sciences, says. "For emerging contaminants in the Arctic, we need to know more about their sources, environmental behavior, and transport pathways in order to regulate them more effectively."

Selin and Carey Friedman, a postdoctoral associate at the MIT Joint Program on the Science and Policy of Global Change, had their latest results published last week in the journal *Environmental Science & Technology*. The study, Long-Range Atmospheric Transport of Polycyclic Aromatic Hydrocarbons: A Global 3-D Model Analysis Including Evaluation of Arctic Sources, describes the researchers' development of a detailed 3-D atmospheric model used to track the day-to-day transport of chemicals. Specifically, they tracked PAHs — toxic

byproducts of burning wood, coal, oil and other forms of energy that remain in the atmosphere for less time than other persistent organic pollutants regulated by global standards.

"Even though our model estimates lifetimes less than a day, that's still long enough for these PAHs to travel long distances and have potentially damaging effects," says Friedman, the study's lead author, noting that some of these chemicals are known carcinogens that could cause cancer. "So PAHs may be a good case study of how we regulate long-range transport."

Friedman's work will be an important foundation for ongoing work in Selin's research group at MIT, in collaboration with the University of Rhode Island and the Harvard School of Public Health. Together the researchers will be exploring the global transport of other contaminants in the Arctic, such as chemicals used in stain-resistant carpets and non-stick pans. In research going forward, Selin and her team will extend the model created in their recent analysis that allows them to track chemicals with much greater precision.

"These more complex models are showing what simple models aren't, such as daily fluctuations of pollutants in specific locations," Friedman says. "So while the simple models are important for some aspects of the policy process, they may not provide enough information to base these types of important decisions off of."

The presence of these pollutants in the Arctic is important for several reasons. First, the researchers say there's a very real health concern. Organic pollutants typically condense and rain down into Arctic regions. Once they mix with other chemicals, it's unknown what danger they could pose to animals and humans, especially in concert with climate change stressors in the Arctic. Already, these chemicals are known to build up in the fat of whales, seals and other animals — a main source of food for people living in these high latitude regions.

At the same time, the practices that create some of these chemicals such as gas and oil exploration and shipping are expected to increase in the Arctic. As they do, it's important to understand how pollutants traveling from distant sources exacerbate the problem, and how climate changes can affect future contamination.

"Climate change and contaminants are both substantial present and future threats to the Arctic, and our research can ultimately help leaders make better policies to protect this unique environment," Selin says. ■

## Meet the Researcher


Carey Friedman is a postdoctoral associate working on simulating long-range atmospheric transport of persistent organic pollutants (POPs) using the GEOS-Chem chemical transport model. She is interested in how transport of POPs to Arctic regions will change with a changing global climate. Carey's long term-research goal is to integrate model-based pollutant transport/behavior predictions with targeted environmental measurements to better assess environmental health risks.

Friedman, C.L. and N.E. Selin, Long-Range Atmospheric Transport of Polycyclic Aromatic Hydrocarbons: A Global 3-D Model Analysis Including Evaluation of Arctic Sources, *Environmental Science & Technology*, 2012.

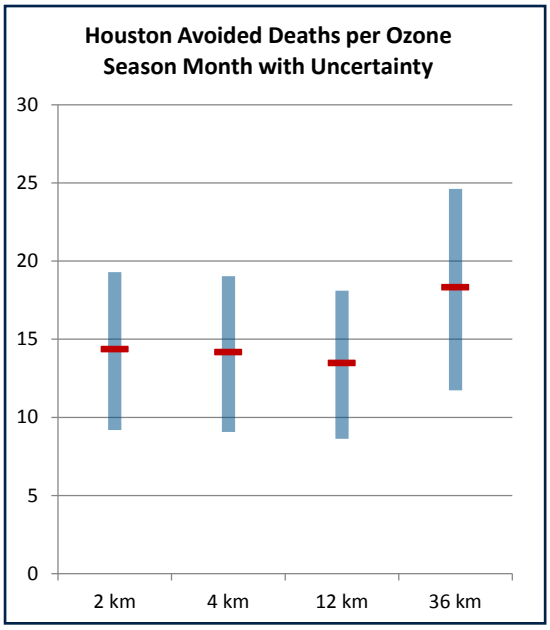
**IN THE NEWS**
Noelle Selin discussed this paper on Alaska's KNOM radio. Listen on our website: http://globalchange.mit.edu/news-events/news/news_id/197

# Influence of Model Resolution on Uncertainty

## *How detailed do models need to be to measure the impact of ozone to human health?*

**Challenge:** Many governments regulate ozone because it is harmful to human health. To provide a better understanding of the full consequences of ozone, and how it could be influenced by climate change, it would be helpful to take uncertainty into account. But while capturing localized ozone requires modeling done at a very fine scale (EPA mandates a resolution of 12 km or finer), uncertainty analyses require a broader scale. These broader, courser models often miss the minimum and maximum concentrations for pollutants — critical information for policymakers.

**Results:** We studied how detailed our models needed to be to measure the impact of ozone on human health, given the great deal of uncertainty. Specifically, we looked at Houston, Texas, because it has a large petrochemical industry, making it ideal for studying point sources of pollution that require fine scale resolutions. In comparing air quality results modeled at multiple resolutions to measured results, we found that the finer the model resolution the closer the results were to modeled results.

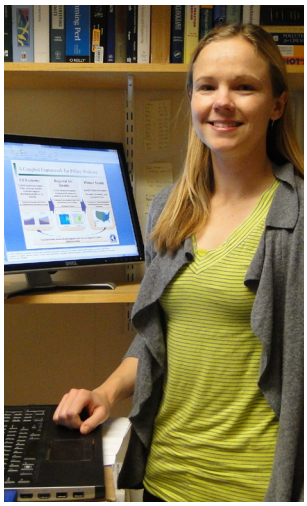



To find out how that pollution was then affecting human health, we overlaid the results with population density and estimated changes in mortalities. From this we found that coarser resolutions tended to over-estimate the human health impacts, but the coarse resolution (36 km) point still fell within the finer resolutions' level of uncertainty. This is significant because it tells us that measuring the impact of ozone policies in Houston using models at 36 km gives results that would be on the high end of what would be found at finer-scale modeling. Our results suggest that it would be better to continue using 12 km resolutions for measuring ozone in cities like Houston.

We're expanding our research to determine what resolutions are required to measure ozone in other areas of the U.S. — including more suburban and rural areas. We're also including the impacts of particulate matter.

Thompson, T.M. and N.E. Selin, Influence of Air Quality Model Resolution on Uncertainty Associated with Health Impacts, *Atmospheric Chemistry and Physics, 2012.*

## Meet the Researcher



Tammy Thompson is a postdoctoral associate working on modeling atmospheric pollution. Her work is expanding the capabilities of global scale modeling efforts by incorporating regional-scale modeling of ozone and particulate matter to evaluate potential air quality and health impacts of transportation policies.

*From*

FOREIGN AFFAIRS

# No Wars for Water: Why Climate Change Has Not Led to Conflict

By: Shlomi Dinar, Lucia De Stefano, James Duncan, Kerstin Stahl, Kenneth M. Strzepek, Aaron T. Wolf

The world economic downturn and upheaval in the Arab world might grab headlines, but another big problem looms: environmental change. Along with extreme weather patterns, rising sea levels, and other natural hazards, global warming disrupts freshwater resource availability — with immense social and political implications. Earlier this year, the Office of the Director of National Intelligence published a report, Global Water Security, assessing hydropolitics around the world. In it, the authors show that international water disputes will affect not only the security interests of riparian states, but also of the United States.

In many parts of the world, freshwater is already a scarce resource. It constitutes only 2.5 percent of all available water on the planet. And only about .4 percent of that is easily accessible for human consumption. Of that tiny amount, a decreasing share is potable because of pollution and agricultural and industrial water use. All that would be bad enough, but many freshwater bodies are shared among two or more riparian states, complicating their management.

*The policy community has long prophesied about the coming water wars. But don't expect them anytime soon. More likely, tensions over access will merely exacerbate existing regional conflicts.*

Of course, the policy community has long prophesied impending "water wars." In 2007, UN Secretary General Ban Ki Moon warned that "water scarcity ... is a potent fuel for wars and conflict." Yet history has not witnessed many. In fact, the only official war over water took place about 4,500 years ago. It was a conflict between the city-states of Lagash and Umma in modern day Iraq over the Tigris river. More recently, there have been some close calls, especially in the arid Middle East. About two years before the 1967 War, Israel and Syria exchanged fire over the Jordan River Basin, which both said the other was overusing. The limited armed clashes petered out, but the political dispute over the countries' shared water sources continues. In 2002, Lebanon constructed water pumps on one of the river's tributaries, which caused concern for downstream Israel. The project never provoked any formal military action, but with peace in the region already precarious, verbal exchanges between the two countries prompted the United States to step in. Both parties eventually accepted a compromise that would allow Lebanon to withdraw a predetermined amount of water for its domestic needs.

In short, predictions of a Water World War are overwrought. However, tensions over water usage can still exacerbate other existing regional conflicts. Climate change is expected to intensify droughts, floods, and other extreme weather conditions that jeopardize freshwater quantity and quality and therefore act as a threat-multiplier, making shaky regions shakier.

So what river basins constitute the biggest risks today?


In a World Bank report we published in 2010 (as well as a subsequent article in a special issue of the *Journal of Peace Research*) we analyzed the physical effects of climate change on international rivers. We modeled the variability in river annual runoff in the past and for future climate scenarios. We also considered the existence and nature of the institutional capacity around river basins, in the form of international water treaties, to potentially deal with the effects of climate change.

According to our research, 24 of the world's 276 international river basins are already experiencing increased water variability. These 24 basins, which collectively serve about 332 million people, are at high risk of water related political tensions. The majority of the basins are located in northern and sub-Saharan Africa. A few others are located in the Middle East, south-central Asia, and South America. They include the Tafna (Algeria and Morocco), the Dasht (Iran and Pakistan), the Congo (Central Africa), Lake Chad (Central Africa), the Niger (Western Africa), the Nile (Northeastern Africa), and the Chira (Ecuador and Peru). There are no strong treaties governing the use of these water reserves in tense territories. Should conflicts break out, there are no good mechanisms in place for dealing with them.

By 2050, an additional 37 river basins, serving 83 million people, will be at high risk for feeding into political tensions. As is the case currently, a large portion of these are in Africa. But, unlike today, river basins within Central Asia, Eastern Europe, Central Europe, and Central America will also be at high risk within 40 years. Some of these include the Kura-Araks (Iran, Turkey, and the Caucasus), the Neman (Eastern Europe) Asi-Orontes (Lebanon, Syria, Turkey), and the Catatumbo Basins (Colombia and Venezuela).

### Crossing the Nile

Among the larger African basins, the Nile has the greatest implications for regional and global security. Tensions over access to the river already pit Ethiopia and Egypt, two important Western allies, against one another. Egypt has been a major player in the Middle East Peace Process and Ethiopia is an important regional force in the Horn of Africa, currently aiding other African forces to battle Al-Shabbab in Somalia.

Over the years, a number of international water treaties have made rules for the basin, but they are largely limited to small stretches of it. In particular, only Egypt and Sudan are party to the 1959 Nile River Agreement, the principal treaty regarding the river. Egypt, which is the furthest downstream yet is one of the most powerful countries in the region, has been able to heavily influence the water-sharing regime. Upstream countries, such as Ethiopia and Burundi, have been left out, hard-pressed to harness the Nile for their own needs.

In 1999, with increasingly vitriolic rhetoric between Egypt and Ethiopia sidetracking regional development, the World Bank stepped up its involvement in the basin. It helped create a network of professional water managers as well as a set of investments in a number of sub-basins. Still, the drafting of a new agreement stalled: upstream countries would not compromise on their right to develop water infrastructure while downstream countries would not compromise on protecting their shares.

In 2010, Ethiopia signed an agreement with a number of the other upstream countries hoping to balance against Egypt and Sudan. More recently, the country has also announced plans to construct a number of large upstream dams, which could affect the stability of the region.

By 2050, the environmental state of the Nile Basin will be even worse. That is why it is important to create a robust and equitable water treaty now. Such a treaty would focus on ways to harness the river's hydropower potential to satiate the energy needs of all the riparian states while maintaining ecosystem health. The construction of dams and reservoirs further upstream could likewise help even out water flows and facilitate agricultural growth. Projects such as these, mitigating damage to ecosystem health and local populations, would benefit all parties concerned and thus facilitate further basin-wide cooperation.

### Up in the Aral

Another water basin of concern is the Aral Sea, which is shared by Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. The basin consists of two major rivers, the Syr Darya and Amu Darya. During the Soviet era, these two rivers were managed relatively effectively. The break-up of the Soviet Union, however, ended that. The major dispute now is between upstream Kyrgyzstan and downstream Uzbekistan over the Syr Darya. During the winter, Kyrgyzstan needs flowing water to produce hydroelectricity whereas Uzbekistan needs to store water to later irrigate cotton fields.

The countries have made several attempts to resolve the dispute. In particular, downstream Uzbekistan, which is rich in fuel and gas, has provided energy to Kyrgyzstan to compensate for keeping water in its large reservoirs until the cotton-growing season. Such barter agreements, however, have had limited success because they are easily manipulated. Downstream states might deliver less fuel during a rainy year, claiming they need less water from upstream reservoirs, and upstream states might deliver less water in retaliation. Kyrgyzstan, frustrated and desperate for energy in winter months, plans to build mega hydro-electric plants in its territory. And another upstream state, Tajikistan, is likewise considering hydro-electricity to satiate its own energy needs. Meanwhile, Uzbekistan is building large reservoirs.

Although these plans might make sense in the very near term, they are inefficient in the medium and long term because they don't solve the real needs of downstream states for large storage capacity to protect against water variability across time. In fact, both Kyrgyzstan and Uzbekistan, along with Kazakhstan, will see substantial increases in water variability between now and 2050. And so, the need to share the benefits of existing large-capacity upstream reservoirs and coordinate water uses through strong and more efficient inter-state agreements is unavoidable.

A stabilized Aral Sea basin would also benefit the United States. With its withdrawal from Afghanistan, Washington has been courting Uzbekistan as a potential alternative ally and provider of stability in the region. The Uzbek government seems willing to host U.S. military bases and work as a counter-weight to Russia. Kyrgyzstan is also an important regional player. The Manas Air Base, the U.S. military installation near Bishkek, is an important transit point. The country is also working with the United States to battle drug trafficking and infiltration of criminal and insurgent groups. Regional instability could disrupt any of these strategic relationships.

If the past is any indication, the world probably does not need to worry about impending water wars. But they must recognize how tensions over water can easily fuel larger conflicts and distract states from other important geopolitical and domestic priorities. Since formal inter-state institutions are key to alleviating tensions over shared resources, it would be wise, then, for the involved governments as well as the international community to negotiate sufficiently robust agreements to deal with impending environmental change. Otherwise, freshwater will only further frustrate stability efforts in the world's volatile regions. ■

SHLOMI DINAR is associate professor in the Department of Politics and International Relations and associate director of the School of International and Public Affairs at Florida International University. LUCIA DE STEFANO is associate professor at Complutense University of Madrid and researcher at the Water Observatory of the Botín Foundation. JAMES DUNCAN is consultant on natural resource governance and geography with the World Bank. KERSTIN STAHL is senior scientist at the Institute of Hydrology in the University of Freiburg. KENNETH M. STRZEPEK is research scientist with the Massachusetts Institute of Technology Joint Program on the Science and Policy of Global Change. AARON T. WOLF is a professor of geography in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University.

# China Energy and Climate Project

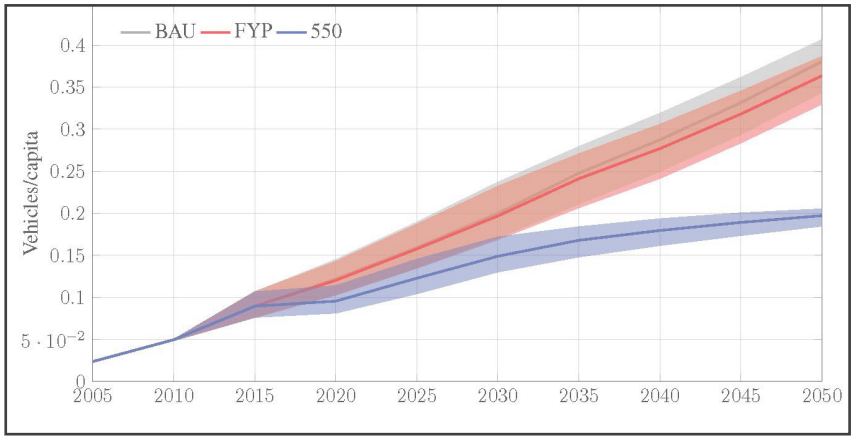
***As the MIT-Tsinghua University China Energy and Climate Project began its second year, the researchers reflected on their progress in five key areas: (1) General integrated assessment of energy and climate policy; (2) Mobility; (3) Low carbon electricity and heat; (4) Industrial energy use and trade; and (5) New model development. Here's what they've found:***

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

*~ Paul Kishimoto*

As Chinese households continue to become wealthier, what impact will this wealth have on their transportation decisions? Will people buy more vehicles because they will have the money to spend on these luxury items? Or will they continue to rely on public transit? We explore the different transportation choices to determine the future impact of those choices on the country's greenhouse gas emissions. To do so, we compare primary energy use and GHG emissions under scenarios which model strong preferences for vehicles, or for public transport.

We also compare those scenarios with and without climate policy. Our analysis finds that climate policy would limit vehicle use and cap demand for oil imports. But without policy, oil use becomes almost as large as coal use in China today and vehicle ownership approaches the present European level. ■




**Per-Capita Vehicle Ownership**
BAU = business as usual FYP=extending current commitments
550= 550 ppm global climate stabilization policy

Kishimoto, P., S. Paltsev and V. Karplus, The Future Energy and GHG Emissions Impact of Alternative Personal Transportation Pathways in China, JP Report 231.

**AWARD WINNER!**

Paul Kishimoto received the Dennis J. O'Brian Student Paper award for related work during the International Association of Energy Economics' Annual Conference in November. Learn more here: http://globalchange.mit.edu/CECP/news/latest/news_id/221

Remember him from the Summer newsletter? Read that profile here: http://globalchange.mit.edu/sponsors-only/Newsletter_Summer2012/StudentSpotlights/Paul

# Quantifying Regional Economic Impacts of $CO_2$ Intensity Targets in China

## *Three Questions with Da Zhang*

**How does this research contribute to on-going research on China?**

In this study, we explain the development of a new computable general equilibrium (CGE) model that looks at China's economy and energy system in 30 provinces. The model allows us to see the tradeoffs to different policy scenarios, such as differences in cost-efficiency and equity among households and regions. In this research we use the model to compare two approaches to setting $CO_2$ intensity targets in China: one is disaggregated at the provincial level (as it is in the five-year plan) and one at the national level with a national carbon trading market set up.

**Why is this model important for China's policymakers?**

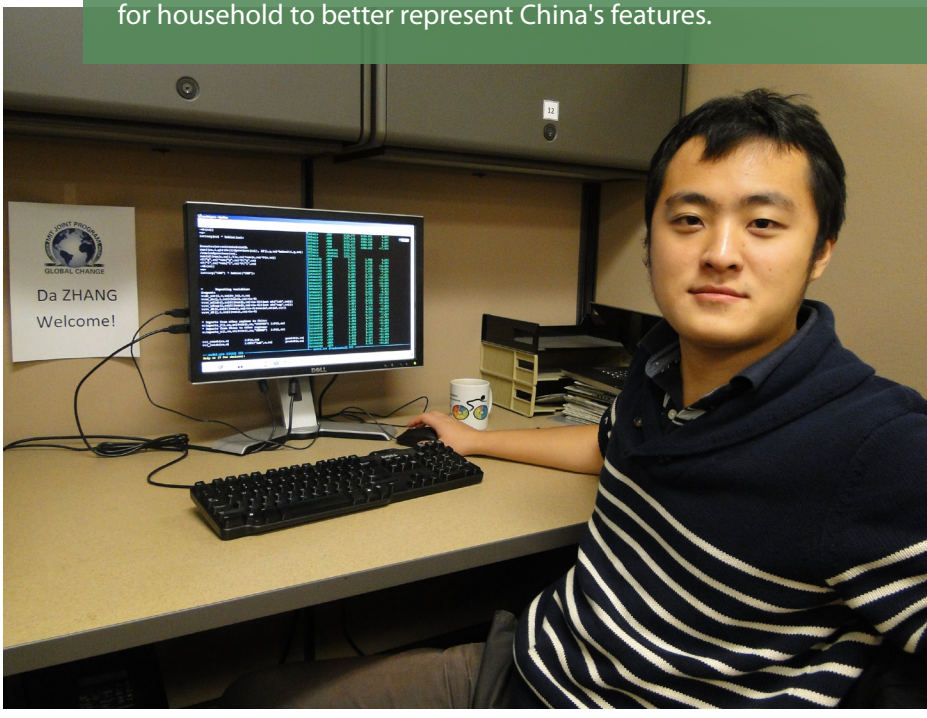
In recent years, China has signaled its strong intention to reduce growing energy and $CO_2$ emissions — including in its most recent five-year plan, which for the first time sets a target to reduce carbon intensity by 17 percent by 2015. Policymakers in China have announced several programs to help the nation meet this target at the provincial level. But along with protecting the environment, leaders in China also want the changes to be fair for all regions and households. They also want to choose policies that will be the most cost-effective. This model is a tool to help policymakers make those types of evaluations.

**What does the model find?**

The model helps us discover that imposing targets at the provincial level results in a welfare loss that is 25 percent greater than if the targets are imposed nationally. This suggests that assigning regional targets may cause China to miss cost-effective opportunities to reduce emissions in less-constrained provinces, while demanding more costly reductions from highly-constrained provinces. In contrast, a national target creates incentives to make reductions where they are most cost effective. ■

Zhang, D., S. Rausch, V. Karplus and X. Zhang, Quantifying Regional Economic Impacts of $CO_2$ Intensity Targets in China, JP Report 230.

Da Zhang is a Ph.D. student working on a multi-region multi-sector multi-household dynamic general equilibrium model of the China economy. He is interested in how China's energy and climate policy will have distributional impacts among different regions and households. Da's long term research goals are to couple bottom-up sectoral models and integrate micro-data for household to better represent China's features.



# Climate Co-benefits of Tighter $SO_2$ and $NO_x$ Regulations in China

## *Three Questions with Kyung-Min Nam*

**How has China's growth impacted its pollution, and what is the country doing about it?**

China's rapid economic growth is in many ways a benefit to its society. But in many other ways, the current growth path is undermining human health and the environment. Power plants and industrial factories spew sulfur dioxide ($SO_2$) that causes acid rain and heart disease, and vehicles and electric generators emit nitrogen oxide ($NO_X$) that leads to smog. Fortunately, China's government realizes the dangers that come with these emissions and they are working to do something about them. In their 12th Five-Year Plan, the government has committed to reduce these emissions by 8 percent ($SO_2$) and 10 percent ($NO_X$), from 2010 levels. The government also has a target to reduce $CO_2$ intensity at 40-45 percent relative to 2005 levels, which is a much more modest target that allows total $CO_2$ emissions levels to continue increasing with economic growth.

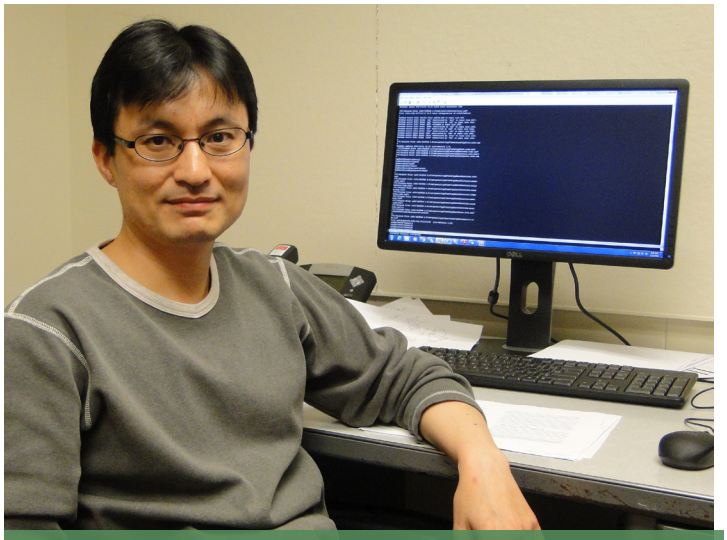
**Will the $SO_2$ and $NO_X$ targets also reduce $CO_2$ emissions?**

Yes. Our research shows that the climate co-benefit from China's tighter $SO_2$ and $NO_X$ control can be substantial. The $NO_X$ and $SO_2$ regulations, for example, will reduce 1.5 bmt of $CO_2$ emissions from the no policy case in 2015 alone (1.5 bmt is equivalent to 22 percent of China's 2010 $CO_2$ emission level). We also found that the $SO_2$ and $NO_X$ regulations would cut $CO_2$ emissions more than the proposed $CO_2$ intensity target would do. That is, with the $CO_2$ intensity target, China would be able to control its total $CO_2$ emissions at around 8.7 bmt by 2015 (24 percent increase from the 2010 level). In the absence of the $CO_2$ intensity target, the $NO_X$ and $SO_2$ regulations would surpass this by helping China control its 2015 $CO_2$ emission level at 8 bmt or only 13 percent increase from the 2010 level. This suggests that China's current $CO_2$ target is too modest to have a significant effect on reducing global $CO_2$ emissions, and thus a more stringent $CO_2$ target is needed.

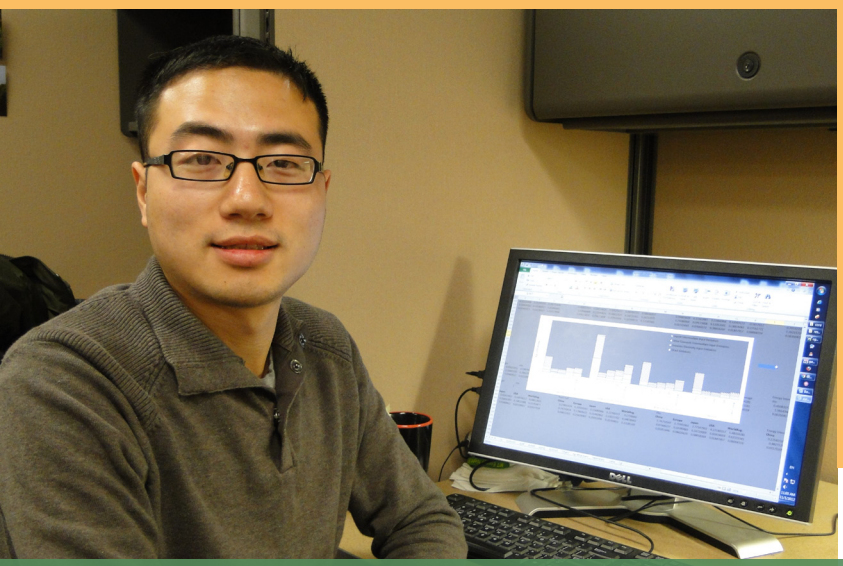
**What will be the cost of achieving these reductions?**

The $SO_2$ and $NO_X$ targets will save China $3 billion in $CO_2$ compliance costs. Energy-intensive industries and the electric power sector would be the ones paying for these savings. These industries have a decision to make. They can either comply with the immediate targets by making temporary fixes — a strategy that will cost them more in the long run — or plan for tighter standards that will come in the future by making major technology changes now. In fact, our analysis shows that China might be able to meet its current near-term $CO_2$ target for the coming decade, while expanding its coal use. This, however, would eventually make future policy compliance costs extremely expensive due to the early lock-in of capital investment in conventional coal technology. This underscores the need for industry, as well as policymakers, to have a forward-looking approach that anticipates more substantial reductions in the future and incorporates new technologies in the short term. ■

Nam, K.-M., C.J. Waugh, S. Paltsev, J.M. Reilly and V.J. Karplus, Climate Co-benefits of Tighter $SO_2$ and $NO_X$ Regulations in China, JP Report 233.



Kyung-Min Nam is a postdoctoral associate. He is interested in the health impacts of air pollution and urban growth projection modeling.



# Will Economic Restructuring in China Reduce Trade-Embodied $CO_2$ Emissions?

~ Tianyu Qi

Tianyu Qi is a Ph.D. student working on establishing a multi-regional, multi-sector recursive-dynamic China in Global Energy Model (CGEM). Detailed description of China's energy and economy characters, such as industry sectors and local information of model calibration, have been involved in CGEM. He is interested in analyzing the impact of carbon trading and carbon tax policies in China and its potential impact on the economy transition and technology improvement in a global context with CGEM.

In 2011, China ranked as the world's largest exporter, as well as the world's largest energy consumer and source of carbon emissions. As developed countries discuss the possibility of imposing a trade tariff on emissions embodied in imported goods to prevent the relocation of high-emitting industries overseas and to shore up domestic competitiveness, we analyze the impact such a change could have on emissions in China and the global total.

Emissions from export activities made up 22 percent of China's total emissions. Europe (360 metric tons), the U.S. (337 metric tons) and Japan (109 metric tons) account for the largest share of these export-embodied emissions. Most of China's emissions come from the production of machinery and equipment, not energy-intensive products like steel and aluminum.

In our analysis, we consider two policies in China. The first is an increase in the tariff on energy-intensive exports from China, which we use to simulate a reduction in export tariff rebates (part of current government policy to selectively promote export growth in particular sectors). The second policy involves incentivizing a shift in China's economy away from industry and towards services. In exploring these policies — both of which are advertised as carbon-reducing strategies — we find that neither would have a significant impact on total global emissions because reduced production in China is partially offset by increased production elsewhere. A policy that targets the expansion of domestic demand is more effective at reducing China's export-embodied $CO_2$ emissions, in turn reducing China's exposure to potential tariffs on embodied carbon imposed overseas. But such a move would also shift production of many industrial products to other nations, shifting emissions along with them. ■

Qi, T., N. Winchester, V.J. Karplus and X. Zhang, Will Economic Restructuring in China Reduce Trade-Embodied $CO_2$ Emissions? JP Report 232.

**ENERGY NIGHT!**

The CECP team presented their research at this year's Energy Night. Despite the rain, more than 1200 guests from MIT, industry, research institutes and the local community came out for the seventh annual event on October 19.

# Clearing the Air

Credit: Dominick Reuter

## Atmospheric Chemist Susan Solomon Finds Hope in Past Environmental Challenges

*By: Jennifer Chu, MIT News Office*

In looking for ways to combat climate change and minimize the planet's warming, atmospheric chemist Susan Solomon says it's often helpful — and heartening — to look to the past.

Solomon points out that recent decades have seen major environmental progress: In the 1970s, the United States banned indoor leaded paint following evidence that it was poisoning children. In the 1990s, the United States put in place regulations to reduce emissions of sulfur dioxide — a move that significantly reduced acid rain. Beginning in the 1970s, countries around the world began to phase out leaded gasoline; blood lead levels in children dropped dramatically in response.

During this period, Solomon herself contributed to a milestone in environmental protection: In 1985, scientists discovered that the Earth's protective ozone layer was thinning over Antarctica. In response, Solomon led an expedition whose atmospheric measurements helped show that chlorofluorocarbons (CFCs) — chemicals then used in aerosols and as coolants in refrigerators and air conditioners — were to blame for ozone depletion. Her discovery ultimately contributed to the basis for the United Nations' Montreal Protocol, an international treaty designed to protect the ozone layer by phasing out CFCs and other ozone-depleting chemicals.

"I find it tremendously uplifting to look back at how our world has changed," says Solomon, now the Ellen Swallow Richards Professor of Atmospheric Chemistry and Climate Science at MIT.

Solomon, a renowned atmospheric chemist who worked for 30 years in Boulder, Colo., at the National Oceanic and Atmospheric Administration (NOAA) and as an adjunct professor at the University of Colorado, is continuing her work in climate research at MIT, where she joined the Department of Earth, Atmospheric and Planetary Sciences in January.

In addition to her research, Solomon is teaching a course, 12.085/12.885 (Environmental Science and Society), exploring how society has tackled a range of past environmental challenges through science, engineering, policy, public engagement and politics.

"I think young people today are growing up at a time when they don't know that we actually have made tremendous progress on a whole series of past environmental challenges," Solomon says. "Climate change has been called the mother of all environmental issues … and I think our approach to this problem

can only be better informed if we understand better what we've done in the past."

### Heading West

Born in Chicago, Solomon was completely taken, from a young age, with "The Undersea World of Jacques Cousteau," a documentary series that followed the legendary marine explorer on his seafaring expeditions. "I pretty much never wavered from the decision right then that I was going to be a scientist," she recalls.

After high school, Solomon enrolled at the Illinois Institute of Technology, where she received a bachelor's degree in chemistry. Continuing her studies in atmospheric chemistry, Solomon moved west, to the University of California at Berkeley. "I had a 1977 Gremlin," Solomon recalls. "It was one of the most awful cars, I think, ever made, but it was really cheap, and I was young and poor. I remember listening to … 'California Dreamin' as I drove out west."

Solomon received her PhD in chemistry from Berkeley in 1981, and went to work as a research scientist at NOAA. In 1985, scientists with the British Antarctic Survey discovered the ozone hole above Antarctica, prompting Solomon to lead expeditions to the icy continent in 1986 and 1987.

"It's the next-best thing to going to another planet," Solomon says of the harsh yet exhilarating experience. "It is the place on our planet that is the most unexplored, the most remote, the most hostile in terms of what the weather and climate is. It is so viciously cold. I just thought it was fantastic exploration, and it's that spirit of exploration that I think is so endemic to science, and is fundamental to everything about Antarctica."

In 2001, Solomon chronicled perhaps the most dramatic exploration of that continent in a bestselling book, "The Coldest March": She used scientific data to examine long-held myths about Robert Falcon Scott, an early-20th-century English explorer who trekked more than 1,000 miles on foot in an effort to become the first to reach the South Pole. But Roald Amundsen, a rival explorer, beat him to the pole by a month, and Scott, along with several team members, perished on the long trek back.

While Scott's expedition had been ridiculed — for example, by some who painted him as a "dyed-in-the-wool Englishman who only wanted to eat tinned mutton," and therefore died of scurvy — letters and diaries from his crew told a different story. Many members of the team described eating fresh seal meat and seal liver, which have been shown to be a good source of the vitamins that ward off the disease. Solomon also analyzed weather data from 1912, and discovered that the crew likely would have survived had they not encountered extreme and unpredictable weather conditions.

"It just seemed to me that somebody needed to go back and take a closer look, with all the diaries of all the guys, and what we know from modern science," Solomon says.

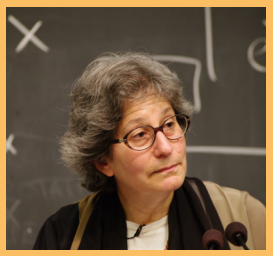
### Changing the Climate

In 2002, Solomon took on another monumental task: leading an international assessment of the scientific work related to climate change. Over six years, she served as co-chair of Working Group 1 of the Intergovernmental Panel on Climate Change (IPCC). In 2007, the group released a comprehensive report on the scientific basis of climate change. Later that year, based in part on the report, the IPCC and former vice president Al Gore received the Nobel Peace Prize.

Solomon continues to seek answers to the most pressing climate challenges. In a widely cited 2009 paper published in the journal *Proceedings of the National Academy of Sciences*, Solomon and her co-authors determined that, even if humans were to immediately and completely stop emitting carbon dioxide, it would take more than 1,000 years to undo existing changes in Earth's surface temperatures, rainfall and sea levels.

This news, while sobering, has not deterred the chemist in her scientific goals. Solomon is currently probing which places on the planet are likely to be the most affected by anthropogenic warming in the near future. In addition to her climate research, she also continues to study the stratosphere — the layer of the atmosphere in which the ozone layer is found.

"There are still fantastic surprises in the stratosphere, as there are in any field, no matter how much has been done on it," Solomon says. "There's always something to discover, and I love that feeling." ■



**WATCH ONLINE!**
On Sept. 13, Solomon gave a talk on "Global Environmental Challenges Past and Future." Read about it, or watch it in full: http://globalchange.mit.edu/news-events/news/news_id/202

# Student Spotlights

*As Arthur Yip joins the Joint Program as a Master's student, Nidhi Santen leaves with her Ph.D. Find out about Santen's time here, and what Yip plans to contribute.*

Arthur Yip sought out MIT's Technology and Policy master's program for a very specific reason. It was the same reason he sought a coveted research position within the Joint Program. And it was the same reason his high school science project failed: Science and policy must work together.

Back in high school, Yip worked with a company that promised to have hydrogen fuel cell-powered cars on the road in five years. It was a similar goal then-President George W. Bush funded.

"Today, people are promising to have a million electric vehicles on the road by 2015. Ten years ago, they were saying the same thing about hydrogen," Yip says. "It didn't work out at all. Large investments were squandered while both our climate and energy security situations continued to deteriorate."

Originally planning on a career in hydrogen and fuel cells, Yip started to rethink the direction he was going.

"I really wanted to learn how government programs and policies could get it so wrong," Yip says. "Fuel cells are really efficient. The idea sounds so neat and tidy. But I found out there were a lot of other things, beyond technology, that didn't get the consideration they should have. In the end, the fuel cells were too expensive and the hydrogen concept didn't make enough sense. A lot of assumptions had been made, but the economic, environmental and social implications were never fully thought through."

Yip went on to do internships in government and industry. He began to see that the problem wasn't just with fuel cell technology. It was a problem within the research, government and industry communities themselves. Through his internships, he saw firsthand the silos of knowledge and research and the barriers to success.

"In the technical community, some people thought they had the best solution and everything else would work out on its own," Yip said. "But on the other side, the policymakers did not fully understand the science and technology either."

Going back to the example of hydrogen vehicles, politicians liked the idea because it deferred some of the hard decisions they had to make and they relied on the promise of technology. But hydrogen was something that needed to be produced, and that would require a lot of energy and infrastructure. Yip says that might have been a concept policymakers didn't fully understand.

Seeing that both sides were important, Yip wanted to be in the middle and take an interdisciplinary approach to solving such problems. That's when he found the Joint Program and the Technology and Policy master's program.

"It's a fairly unique program because it's not a dual degree where there's a mix of art and science, but we have courses and research work that weave both together," Yip says, applying the same dynamic to the Joint Program.

Yip brings this perspective to his research with Sergey Paltsev, as this year's BP fellow. He hopes to apply his interdisciplinary way of thinking to the concept of natural gas vehicles.

"We recently found we have more natural gas than we thought. An interesting question is, what can this natural gas do for society? Will it help us mitigate climate change? Will it help the U.S. gain energy independence?" Yip asks.

He explains that these are two competing objectives. For natural gas to lower emissions, it would need to displace coal used for electricity production. To lower the nation's

reliance on foreign oil imports, natural gas could be deployed as a fuel for transportation to displace oil. Both have important implications.

"These questions really fit into an economic model like the Emissions Predictions and Policy Analysis (EPPA) model because it's all about limited resources and deciding how best to allocate those resources," Yip says.

To apply the lessons learned from hydrogen cars, Yip wants to look into proposed policies such as an open fuels standard to help policymakers understand what could go wrong if they do choose to adopt the standard.

The open fuels standard would require automakers to make flexible fuel vehicles that could run on gasoline, ethanol and methanol, which could be produced from natural gas. This would give consumers more choices at the pump, and likely save them money. This would also help reduce oil imports. But what about the implications and costs for society?

"I want to investigate the full opportunity costs of the new engines, infrastructure, and the natural gas itself, because there is a high risk of waste and inefficient allocation. There may be better options in terms of net societal benefit, and policies should be designed with this in mind," Yip says. ■

**FELLOWSHIPS**
Arthur Yip is this year's BP Fellow for the Joint Program. Does your organization sponsor fellowships? Consider sponsoring an MIT student.

# Arthur Yip: Connecting Science and Policy

# Nidhi Santen: New Energy Technology in an Uncertain World

When Nidhi Santen was just about six years old she went on an overnight trip with her Brownie troop. The same night her older brother went on a trip with the Cub Scouts. She came home with an air freshener she had made after sleeping in the local elementary school. Her brother came home with a pet frog after spending the night camping by a pond. Frustrated she didn't get to do "cool things," Santen became an honorary (tag-along) Cub Scout, and her love of the environment grew more each day.

Now Santen follows her passion to protect the environment by studying something most take for granted: Electricity.

"Electricity is one element that affects almost every sector of our economy. We use it without really thinking, and there's a lot that goes into designing the system so we can just flick a switch," Santen says. Yet because electric generation comprises about 40 percent of the carbon emissions in the U.S., "doing something about this sector is really important if we're going to address environmental challenges such as climate change."

Plus, Santen — a self-described electricity geek — adds, "Seeing the inner workings of a power plant, and how it makes electricity, is amazing."

This October Santen finished her doctorate in Engineering Systems, where she focused on long-term capital and R&D investment planning for the U.S. electric power generation sector, in the face of climate change. Specifically, she looked at how best to balance efforts in research and development of new technologies versus building already available technologies in the electric power sector. The challenge in finding this (cost-effective) balance arises from the fact that (1) continued electricity demands require some upfront installation of very long-lived, potentially high-carbon, commercially available technologies; and (2) R&D into new technology areas might allow potentially lower-carbon technologies to be competitive soon, but with some uncertainty.

"R&D programs are fundamentally uncertain. So if you have a cumulative environmental (e.g., carbon) target to meet and a finite amount of money, should that money be invested in building new commercially available power plants, or do you put $2 million into a company that's really excited about their new solar panels or new

wind turbines or new method of extracting carbon?" Santen says.

Santen's study helps government agencies make those decisions by creating a new modeling framework. Unlike current models used by the U.S. Energy Information Administration or several government and academic research institutions, her method allows researchers and policymakers to consider what is known and unknown today, and make short-term decisions based on those uncertainties.

"Right now the types of models government and research institutions are using assume that we know how R&D programs are going to turn out, and we don't," Santen says. "They also assume that you're not going to in 10 years from now reassess, look back on how things went, and reconsider your next decision. And we know that's not how real people make decisions. Real people make decisions by evaluating the best choice now, given what they know, and later change their path based on what they learned."

When applying this method, Santen found that when uncertainty is factored into these decisions, the amount one would invest in R&D is different from when uncertainty and learning is not formally considered. For example, if by 2060 emissions need to be reduced by a certain level, power plants may not need carbon capture and storage technology working immediately to meet the cap. There may be some time to wait and learn.

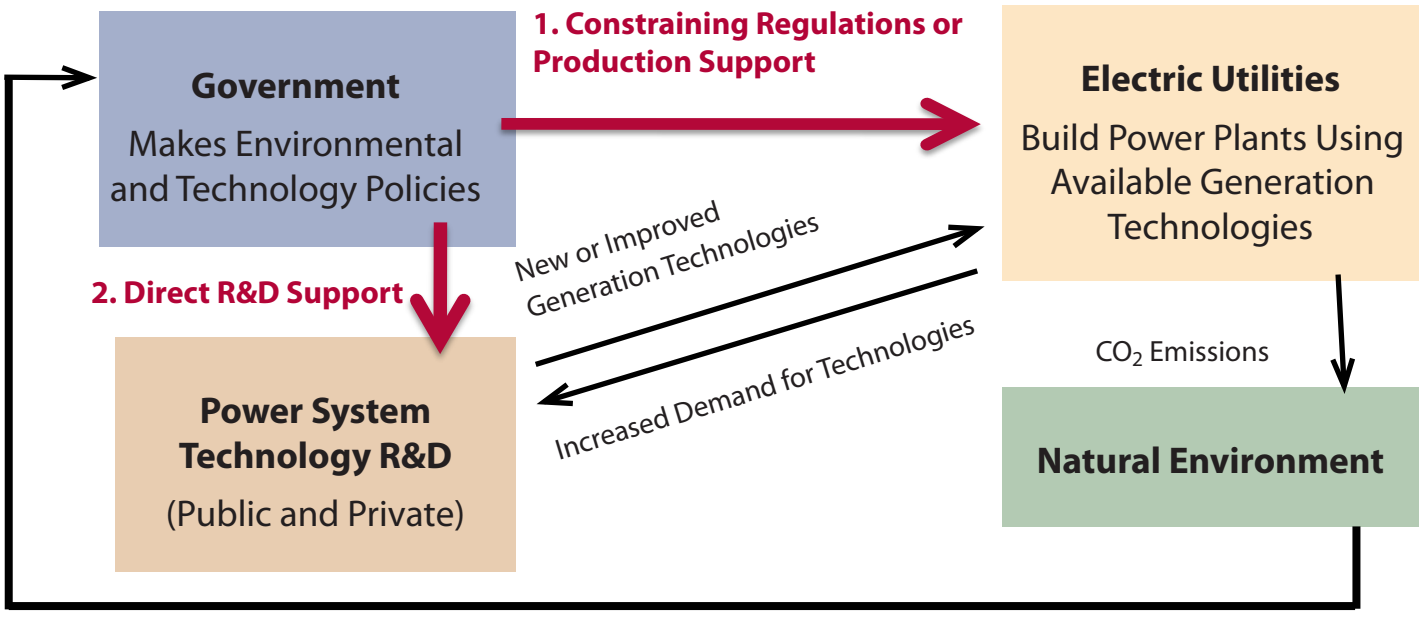
"The model tells you to invest less in R&D because it knows you have time to make decisions in the future and see what happens with R&D outcomes in the meantime," Santen says, "But in the no uncertainty model, it thinks you don't have any other chances to change your investment levels, so it tells you to invest more heavily now."

Santen hopes her new method will help to improve models that work at a more industrial level, such as the NREL ReEDS model. She looks forward to continuing her work on electricity planning and environmental policy analysis as a postdoctoral research fellow at the Harvard Kennedy School of Government Belfer Center for Science and International Affairs. ■

**Two main policy pathways to reduce cumulative power sector emissions:**

**"Now vs. Later"**

**"Deployment vs. Development"**



# The Environment @ MIT

MIT and the Joint Program kicked off the school year with many events centered around energy, the environment and global change.

## New Series! Geoengineering: Science & Governance

*Sponsored by the Joint Program and the Harvard University Center for the Environment.*

Solar geoengineering is the concept of deliberately cooling the Earth by reflecting a small amount of inbound sunlight back into space. It is the only currently known method for reducing temperatures in the short term (years to decades), and therefore has the potential to reduce many of the worst impacts of global warming. But what would be the side effects, both physical and socio-political? How would it work and who gets to decide if it is deployed? Does humanity have the wisdom and the institutions to govern the development of such a powerful technology in this messy, multi-polar world? The Joint Program, along with the Harvard University Center for the Environment, is jointly hosting a new seminar series on this important topic. It explores the science, technology, governance and ethics of solar geoengineering. The series kicked off on Thursday, October 25 with a lecture by Harvard's David Keith on "The Risks and Efficacy of Solar Geoengineering."


Learn more about the series: http://globalchange.mit.edu/news-events/communications#seminars

## MIT Museum: Climate & Conflict

Inspired by the response to their "Rivers of Ice" exhibition and ongoing public concerns about the absence of climate change in the presidential campaign, the MIT Museum held a soap box series of lectures this fall. On Tuesday, October 16, Co-Director John Reilly was the featured speaker. Reilly talked about the economics surrounding climate change. Noting that New England's weather will become more like that of Virginia or North Carolina over the next decade, Reilly said that doesn't mean we'll be saving money on heat. In exchange for heating bills we'll be paying for air conditioning, on top of the costs that come with storms, flooding, erosion and other side effects to climate change. What can we do about it? Reilly said economists are always finding reasons why solutions won't work. Displaying his "lemon sucker" award, he explained that during the Clinton administration economists were pegged as lemon suckers because of the face they would make in response to climate fixes. For example, tax incentives for renewable energy or energy efficiency measures "might be getting us going," Reilly said, but people don't realize that while the money isn't coming out of our front pockets, the incentives need to be paid for by raising other taxes. "So they're taking the money out of our back pockets instead," Reilly said. These incentives also hide the fact that energy is expensive. Instead of hiding this fact, Reilly suggests a carbon tax would be a better alternative because people would see that energy is expensive and work to reduce their use. The money raised from these taxes could then be used to cut other taxes. If these taxes are made gradually and efficiently, we would have time to make energy efficient changes, like more efficient vehicles and better insulated homes.


Watch the full event, and learn more about the series: http://globalchange.mit.edu/news-events/featured-events/event_id/511


**Global Systems 2.0:** Among the most noteworthy visits this fall came from the Tibetan Buddhist leader the Dalai Lama, who called for increasingly enlightened stewardship of Earth's environment and resources in public remarks on Monday, October 15.

"We have the responsibility to take care of the whole planet," said the Dalai Lama, the exiled leader of Tibetan Buddhism, adding: "It is not a luxury, it is a matter of our own survival."

The Dalai Lama's remarks came during a pair of panel discussions he participated in, focused on the ethical and social challenges of climate change and resource scarcity — including the limited availability of food and water for a global population that is 7 billion and growing rapidly.

Learn more about the Dalai Lama's visit: http://globalchange.mit.edu/news-events/news/news_id/209


**Women in Clean Energy:** Female leaders are playing a growing role in advancing the development of clean-energy. Some of these women were honored in a daylong symposium at MIT on September 28 — the inaugural event of an initiative, created in 2010 by the U.S. Department of Energy with eight partner governments, called Clean Energy Education and Empowerment, or C3E. More: http://globalchange.mit.edu/news-events/news/news_id/207

**Energy Debate:** The MIT Energy Initiative took part in the presidential campaign by hosting an energy debate on October 5. The debate featured Oren Cass, policy director for Republican Mitt Romney, and Joe Aldy, a professor at Harvard University's Kennedy School of Government who served as a special assistant to President Obama for energy and environment in 2009 and 2010. More: http://globalchange.mit.edu/news-events/news/news_id/208

**Predicting Climate in a Chaotic World:** On Thursday, November 1, MIT joined with the New England Aquarium in hosting Timothy Palmer, the Royal Society Professor of Climate Physics at Oxford University. Palmer explained why the climate system is so uncertain, and noted that the scientific community has the capabilities to erase much of this uncertainty, but does not have the funding. Watch the event: http://globalchange.mit.edu/news-events/communications/35

**Chasing Ice: Adam LeWinter:** Chasing Ice, a film on one man's mission to change the tide of history by gathering undeniable evidence of climate change, was released this November. To kick off the film's debut in Cambridge, the Joint Program and MIT Energy Club hosted Adam LeWinter, from the film's cast, on November 16. Learn more about LeWinter and the film: http://globalchange.mit.edu/news-events/featured-events/event_id/520

**Watching the Arctic Melt: Adventures in Polar Oceanography:** On the heels of "Chasing Ice," researchers from MIT and Woods Hole Oceanographic Institution discussed what's happening at the top of the world, how we know about it, and why it matters on Monday, November 19. More: http://globalchange.mit.edu/news-events/featured-events/event_id/521

### Climate Change and Water Resource Impacts

***Project Leaders: John Reilly***

From increasing urbanization to climate change, a number of factors are leading to reductions in the amount of water available for irrigated agriculture. Understanding how agricultural production will change in response to these constraints is critical to studying agricultural policies and to understanding the impacts of a climate change. This project will seek to identify the impacts of competing demands and climate change on agricultural water availability — considering trends in agricultural productivity and irrigation demand, with a focus on regions of emerging agricultural water scarcity.

**Source: U.S. Department of Agriculture**

### The Commercial Potential of Biofuels in a Resource-Constrained World

***Project Leaders: John Reilly and Niven Winchester***

The project will provide a quantitative evaluation of the commercial potential for biofuels produced through a variety of pathways and using a range of crops (current food/feed crops and dedicated grasses or woody crops), including representation of constraints (imposed by physical limits or related policy) due to water and land availability, greenhouse gas (GHG) emissions and food prices.

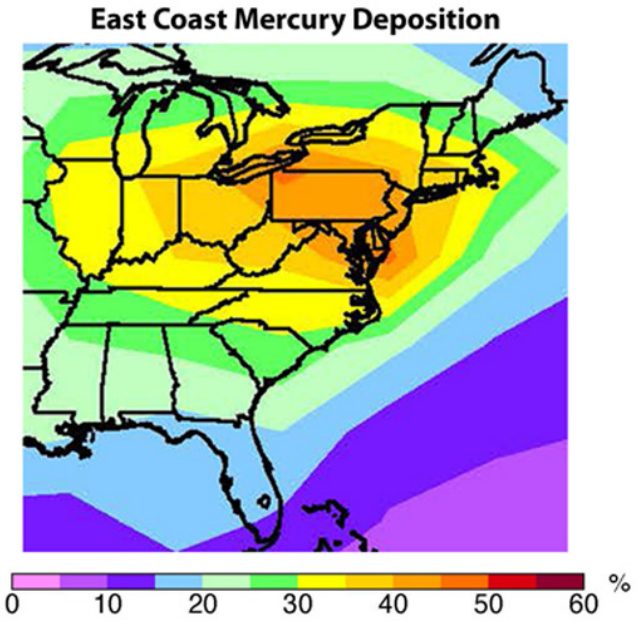
**Source: BP**

### Mercury in the Atmosphere Over the Eastern United States

***Project Leaders: Noelle Selin, Christopher Cantrell (Univ. of Colorado at Boulder), Daniel Jaffe (Univ. of Washington)***

Human exposure to mercury is a significant health risk and a problem of national and global significance. This project comprises the first large-scale airborne experiment focused on mercury over North America. The results will reduce the uncertainties concerning source-receptor relationships and the relative contributions of domestic, foreign and natural sources to the inventory of atmospheric mercury over the eastern U.S.

**Source: U.S. National Science Foundation**

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## Coming and Going

**Rotem Bar-Or** joined as a postdoctoral associate. He will be working with Chien Wang.

**Michael Davison**, a Ph.D. candidate, joined as a research assistant and the ICF fellow for the China Project.

**Paul Kishimoto**, who graduated from the Technology and Public Policy master's program, will continue his work with the China Project as a research associate.

**Megan Lickley**, who graduated from the Technology and Public Policy master's program, continues her work with the Program as a research associate.

**Eri Saikawa** was promoted to research scientist.

**Arthur Yip**, a master's candidate in the Technology and Public Policy program, joined as a research assistant and BP fellow. He will be working with Sergey Paltsev.

**Alvaro Lopez-Pena Fernandez** joined as a visiting student from Upcomillas University in Madrid, Spain.

**Charles Fant** and **Yohannes Gebretsadik** joined as visiting students from the University of Colorado, Boulder. They will be working with Ken Strzepek.

**Yongxia Cai**, a research scientist, left for RTI.

## Newly-Released Joint Program Reports

**Report 233:** Climate Co-benefits of Tighter $SO_2$ and $NO_x$ Regulations in China

**Report 232:** Will Economic Restructuring in China Reduce Trade-Embodied $CO_2$ Emissions?

**Report 231:** The Future Energy and GHG Emissions Impact of Alternative Personal Transportation Pathways in China

**Report 230:** Quantifying Regional Economic Impacts of $CO_2$ Intensity Targets in China

**Report 229:** CLM-AG: An Agriculture Module for the Community Land Model version 3.5

**Report 228:** Carbon Tax Revenue and the Budget Deficit: A Win-Win-Win Solution?

**Report 227:** Impacts of Land Use and Biofuels Policy on Climate: Temperature and Localized Impacts

## Forthcoming Joint Program Reports

Modeling Water Resource Systems Under Climate Change: IGSM-WRS

Informing the Response to Rising Coastal Flood Risk

Non-nuclear, Low-carbon, or Both? The Case of Taiwan

Analyzing the Regional Impact of a Fossil Energy Cap in China

Multiple Adaptation Types with Mitigation: A Framework for Policy Analysis

Modeling Adaptation as a Flow and Stock Decision with Mitigation

Water-$CO_2$ Tradeoffs in Electricity Generation Planning

## Peer-Review Studies/ Pending Reprints

Shale Gas Production: Potential Versus Actual GHG Emissions, *Environmental Research Letters*

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

Applying Engineering and Fleet Detail to Represent Passenger Vehicle Transport in a Computable General Equilibrium Model, *Economic Modelling*

Should a Vehicle Fuel Economy Standard be Combined with an Economy-wide Greenhouse Gas Emissions Constraint? Implications for Energy and Climate Policy in the United States, *Energy Economics*

Out of Passivity: Potential Role of Outward Foreign Direct Investment in Inward Foreign Direct Investment-based Learning Trajectory, *Industrial and Corporate Change*

Green Growth and the Efficient Use of Natural Resources, *Energy Economics*

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

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

## Newly-Released Joint Program Reprints

**Reprint 2012-29:** The Economic, Energy, and GHG Emissions Impacts of Proposed 2017-2025 Vehicle Fuel Economy Standards in the United States, *Transportation Research Record*

**Reprint 2012-28:** Quantifying the Likelihood of Regional Climate Change: A Hybridized Approach, *Journal of Climate*

**Reprint 2012-27:** Food Benefit and Climate Warming Potential of Nitrogen Fertilizer Uses in China, *Environmental Research Letters*

**Reprint 2012-26:** The Impact of Climate Change on Crop Yields in Sub-Saharan Africa, *American Journal of Climate Change*

**Reprint 2012-25:** Influence of Air Quality Model Resolution on Uncertainty Associated with Health Impacts, *Atmospheric Chemistry and Physics*

**Reprint 2012-24:** The Canadian Oil Sands Industry Under Carbon Constraints, *Energy Policy*

**Reprint 2012-23:** Characterization of Wind Power Resource in the United States, *Atmospheric Chemistry and Physics*

**Reprint 2012-22:** Changing the Climate Sensitivity of an Atmospheric General Circulation Model through Cloud Radiative Adjustment, *Journal of Climate*

**Reprint 2012 17-21:** Special Issue: Climate Change and Economic Development, *Review of Development Economics*

**Reprint 2012-16:** Marginal Abatement Costs and Marginal Welfare Costs for Greenhouse Gas Emissions Reductions: Results from the EPPA Model, *Environmental Modeling and Assessment*

**Reprint 2012-15:** Long-Range Atmospheric Transport of Polycyclic Aromatic Hydrocarbons: A Global 3-D Model Analysis Including Evaluation of Arctic Sources, *Environmental Science & Technology*

## Joint Program In the News

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

**November 15,** *Bloomberg*, Carbon Fee From Obama Seen Viable With Backing From Exxon

**November 14,** *Reuters*, Prediction tool could help regional disaster planning - researchers

**November 13,** *Wall Streeet Journal*, Carbon Tax Idea Gains Wonkish Energy; *Nature*, America's carbon compromise, Obama reasserts research focus; *Washington Post*, A carbon tax would allow us to cut other taxes – but not much

**November 9**, *Reuters*, U.S. carbon tax works, with support: Wynn; *Washington Post*, With 'fiscal cliff' looming, carbon tax getting closer look; *Politico*, Carbon tax faces long odds in fiscal cliff battle

**October 12**, *BBC Business Daily*, USA's Climate Change

**October 5,** *Mozambique News Service*, Mozambique: Researchers Warn Climate Change Will Hit Roads

**September 24** , *AP*, Despite the Weather, Climate Change Gets Little Mention in the Campaign

**September 11**, *Globe and Mail*, Changing Climate and a Much-Needed Carbon Tax

**September 7,** *Discovery News*, Hurricane Link To Climate Change Explained

**August 28**, *Reuters*, Carbon tax could rescue U.S. budget deficit: MIT; *Bloomberg BNA*, Carbon Tax Could Raise $1.5 Trillion as Federal Deficit Looms

**August 27**, *Washington Post*, How a carbon tax could help the U.S. avert the fiscal cliff; *The Hill*, Study: Carbon tax could raise $1.5 trillion

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