GLOBAL CHANGES

MIT Joint Program on the
Science and Policy of Global Change

Professor Henry "Jake" Jacoby steps down as co-director of the Joint Program

MIT Joint Program welcomes new co-director John Reilly

Distributional Implications of Alternative U.S. Greenhouse Gas Control Measures

The Future of U.S. Natural Gas Production, Use, and Trade

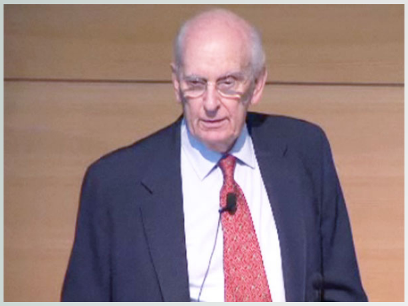
Combining a Renewable Portfolio Standard with a Cap-and-Trade Policy

On the Correlation between Forcing and Climate Sensitivity

Fall 2010 Newsletter

MIT Joint Program Symposium
Tribute to Prof. Henry "Jake" Jacoby
Perspectives on Energy and Climate Policy Research
June 24, 2010

Professor Ronald G. Prinn, co-director of the Joint Program, moderated the symposium to honor Prof. Jake Jacoby. The afternoon consisted of a series of guest lectures representing colleagues, collaborators, and sponsors who paid tribute to the co-founder and co-director of the Joint Program.



Professor William F. Pounds, Dean Emeritus, MIT Sloan School of Management, speaking at Jake's symposium: "To be at MIT when energy and the environment were just beginning to move into the public consciousness was to be where the most serious such work was being done [...] Jake's efforts to create successful research centers has made MIT and all of us more serious contributors to the energy and environmental policy debate than we would have been otherwise."

http://globalchange.mit.edu/images/poster-Jacoby-Tribute.pdf

GLOBAL CHANGES

The Joint Program integrates natural and social science to produce analyses relevant to ongoing national and international climate policy debates

News and Events

Graduated Students and Completed Post-Docs

Eleanor Ereira (Master of Science, Herzog and Webster)
Assessing Early Investments in Low Carbon Technologies under Uncertainty: The Case of Carbon Capture and Storage

Oghenerume Kragha (Master of Science, Reilly)
Economic Implications of Natural Gas Vehicle Technology in U.S. Private Automobile Transportation

Asuka Suzuki-Sato (Master of Science, Schlosser)
Impacts of Climate Policy on Urban Air Pollution: Implications for Policy Design for Integrating Air-quality Co-benefits

Jason Cohen (Doctor of Science, Prinn)
Urban-Scale Impacts on the Global-Scale Composition and Climate Effects of Anthropogenic Aerosols

Kyung-Min Nam (Doctor of Philosophy, Amsden)
Foreign Direct Investment, Intra-organizational Proximity, and Technological Capability: The Case of China's Automobile Industry
Continuing as post-doc (Reilly), air pollution health impacts and urban growth projection modeling

Jaemin Song (Doctor of Engineering Systems, Reilly)
The Road to the Successful Clean Development Mechanism: Lessons from the Past

Gill-Ran Jeong (Post-Doc, Wang)
Modeling of anthropogenic aerosols

New Students and Post-Docs

Michael Byrne (Doctoral, O'Gorman)
The response of the hydrological cycle to climate change

Cuicui Chen (Masters, Reilly) Economics of biofuels

Pearl Donohoo (Doctoral, Webster)
Renewable energy integration into the US power system

Megan Lickley (Masters, Jacoby) Coastal impacts of climate change

Claudia Octaviano (Doctoral, Webster)
Greenhouse gas mitigation in Mexico

Katherine Saad (Doctoral, Prinn)
Modeling the climatic impact of the aviation industry

Rebecca Saari (Masters, Selin)
Health impacts of atmospheric pollution

Bhaskar Gunturu (Post-Doc, Schlosser; Doctor of Science 2010)
Potential climatic impacts of large-scale deployment of renewable (wind and solar) technologies
Aerosol-Cloud Interactions: A New Perspective in Precipitation Enhancement

Willow Hallgren (Post Doc, Schlosser)
Potential climatic and land-use impacts under scenarios (wind & solar)

Carey Friedman (Post-Doc, Selin)
Modeling of atmospheric chemistry and organic pollutants and the implications for health impacts

Qudsia Ejaz (Post-Doc, Paltsev and Reilly)
Indirect land use emissions from biomass based jet fuels

XXXI MIT Global Change Forum
Confronting Domestic and Global Climate Strategies

In collaboration with the Université catholique de Louvain, Center for Operations Research and Econometrics (CORE) and Chair Lhoist Berghmans

October 20-22, 2010
Brussels, Belgium

Session topics include:

- Lessons from Past Interglacial Climates
- Forecasting Climate at the Regional Level
- Global Economics, Global Trade and its Carbon Content
- Consequences of Diverse Domestic Carbon & Energy Politics
- Goals and Challenges in Assessing the State of the Science
- The Road To and From Cancun

Forum attendance is by invitation only.

XXXII MIT Global Change Forum

The following MIT Global Change Forum will be held in Cambridge, Massachusetts, in June 2011. Forum attendance is by invitation only. More information to follow.

Professor Henry "Jake" Jacoby steps down as co-director of the Joint Program

Prof. Henry D. Jacoby

Professor Jake Jacoby, co-founder of MIT's Joint Program on the Science and Policy of Global Change, stepped down this June from his long-held position as co-director. Twenty years ago, the Center for Energy and Environmental Policy Research's (CEEPR) 25 years of work in energy and economics was combined with the huge body of scientific research and experience of the Center for Global Change Science (CGCS) to create an integrated program. Jake, Professor Ronald Prinn, and the other founding members quickly realized that "If we were going to write a grant, we needed a name to put at the top. So the name comes from the joint venture between CEEPR and CGCS, working together on the science and policy of global change.

What made the initial development of the Joint Program possible was the nature of MIT. "MIT makes it easy," explains Jacoby. "Other universities have a much harder time integrating across disciplines. But it's in the DNA of MIT to do this kind of thing." Professor Jacoby's entire career has focused on the integration of social science, particularly economics, with natural science and engineering. He has worked across a wide range of issues, starting with water problems and moving on to air pollution, energy, and finally climate issues— always going after the next big problem "that was not really susceptible to being solved just by the economists, or just by the scientists, or just by the engineers."

In one sense, the field of climate change has not evolved much over Jake's tenure at the Joint Program, as little has been done politically in the past 20 years. Jake attributes much of this lack of change to the difficulty of the climate problem— including distributional issues, questions of governance, and the fact that it's a complicated issue for people to understand. "Gaining public understanding and support is extra difficult," Jake explains. "In terms of our ability to deal with the issue, not much has happened in the last 20 years. Lots of talk, lots of analysis, not much action."

On the other hand, Jake notes that the area of global change has exploded in terms of the number and diversity of people conducting relevant scientific and economic research, the amount of money involved, and the number of institutions and international meetings devoted to the subject. The Joint Program has contributed to this explosion by being influential as an independent source for integrated analysis.

Looking forward, though Professor Jacoby will be less engaged in the management of the Joint Program, he will continue to be involved in research. He intends to follow up on studies regarding sea level rise and severe storms— a return to the kind of work he did early in his career on water resources—while continuing to dig into policy issues and discussions

Dr. John M. Reilly appointed new co-director of the Joint Program

John Reilly may be taking over new responsibilities as co-director, but he is far from new to the Joint Program. His interest in integrated assessment started in the early 1990's, while contributing to the identification of research priorities within the US Global Change Research Program. The MIT Joint Program on the Science and Policy of Global Change was formed in 1991 to undertake just such research. Reilly came as a visitor to the Program for a year in 1992-1993 and left the department of agriculture to join the Joint Program permanently in 1998. While at MIT, John has conducted research across a broad set of topics in energy, environmental, and agricultural economics as they relate to climate change. Most recently, John has focused on the environmental and economic effects of adopting alternative energy and fuel technologies, particularly biofuels.

When asked how his field of research has evolved over his tenure with the Joint Program, John Reilly points out three major areas of change. First, John noted that "in the early days we were doing these very simple studies: let's put a global cap-and-trade system on and see what it does and ask what it costs." While economists still favor an incentive-based approach like a cap-and-trade or emissions tax as the most efficient method of reducing emissions, in reality different governments are adopting a mix of varying policy measures— requiring that a more complex set of policy instruments be evaluated. Second, over time the type of industries interested in the issue has expanded. In the last 5-10 years interest in climate change has grown to include a much wider spectrum of companies, as they have begun to consider how climate change will affect their businesses.

A final area of change within his field has been the expansion of adaptation studies. Thirty years ago the problem seemed a long ways away- in part because it was. But after thirty years of inaction, the problem is much more immediate. Combined with the fact that the science has improved and shown significant risks from impacts, climate change has become a problem that is "not just going to affect our children's children, but is affecting us now".

While John has taken on increased administrative duties, he still plans on staying involved in key research projects. Because the Joint Program conducts integrated assessment, studies range across a wide array of issues and are forever spinning off in new directions. "If we don't continue to expand the depth and detail of our research then we become less relevant— because we aren't dealing with the issues as they're evolving. And if we don't push forward on a number of fronts than we fail in our core mission of bringing an integrated view to the problem of climate change" Reilly observes. With enthusiasm for the principles that the Joint Program was founded on as well as the possibilities within these new directions, John looks forward to continuing his research while taking on the new responsibilities of co-director.

Dr. John M. Reilly

Report 185: Distributional Implications of Alternative U.S. Greenhouse Gas Control Measures

Analysis shows that, contrary to some claims, proposed legislation to limit carbon emissions would not disadvantage those with lower incomes.

David L. Chandler, MIT News Office
http://web.mit.edu/newsoffice

So-called "cap and trade" legislation has often been portrayed as a regressive policy — one that would hit poor people the hardest. A new MIT study concluded that this is not the case.

The U.S. House of Representatives passed a cap-and-trade bill last year, and different versions of that bill had been working their way through the Senate until being yanked from consideration last month.

The study, co-authored by researchers at the MIT Joint Program on the Science and Policy of Global Change and at Tufts University, found that under all three versions of the bill submitted so far, the costs would fall hardest on wealthier households, and that lower-income households would see no change or a net benefit.

The basic concept of cap and trade is that greenhouse-gas emissions would be capped at some level (usually about the present level, or the level from a past year), and companies that produce those emissions, such as electric utilities, would receive permits for a given amount. If they choose to install lower-emissions plants, they would end up with extra permits, which could then be freely traded - that is, sold to companies that are unable to stay within their allotted limits.

The MIT study assumed that a cap-and-trade measure would take effect in 2012, and it estimated the legislation's financial effects on U.S. households beginning in 2015 and continuing every five years through 2050.

It found that incomes of the poorest Americans — households that earn less than $10,000 a year — would show a net increase of up to 1.5 percent in 2015, depending on the particular bill. Households earning less than $50,000 a year — about 45 percent of all households — would see some gains, or at worst no change. Those in the very highest income bracket would pay more, with total additional costs in 2015 amounting to less than 0.5 percent of their incomes. According to the study, these effects would become more pronounced over time.

The research, published this last month [July] in the Berkeley Electronic Journal of Economic Analysis and Policy, was unique in its analysis of both the income and expense impacts of the legislation, and of regional differences on a scale that in some cases went down to the level of individual states.

Older computer models used to analyze the impacts of cap-and-trade legislation just looked at one or two typical households, explains John Reilly, co-director of the MIT Joint Program and one of the authors of the new study. "We decided to look at how carbon policies are going to affect different people," Reilly says. "Conventional wisdom holds that by raising the cost of energy, policies to price carbon will have a negative effect on everyone," he says. "Our research concludes that, by itself, pricing carbon tends to be progressive, rather than regressive."

Graphic: Christine Daniloff

The database developed by the team, which also included researchers Sebastian Rausch and Sergey Paltsev of the MIT Joint Program and Gilbert Metcalf of Tufts, breaks the information down regionally, as well as by income level.

Overall, for all the different regions and income levels, the results were quite consistent: Those with the lowest incomes came out ahead, while those with higher incomes bore most of the additional costs. Reilly calls this finding "really unexpected," and attributes it primarily to the fact that the study looked at both households' incomes and expenses.

To understand why poorer households may fare better than richer ones, consider that those in the lowest income echelons tend to derive a larger portion of their incomes from government programs such as welfare or Social Security. These programs are all indexed to inflation, and because the cap-and-trade measures are expected to add to the cost-of-living index, those increases would be compensated by the adjustments.

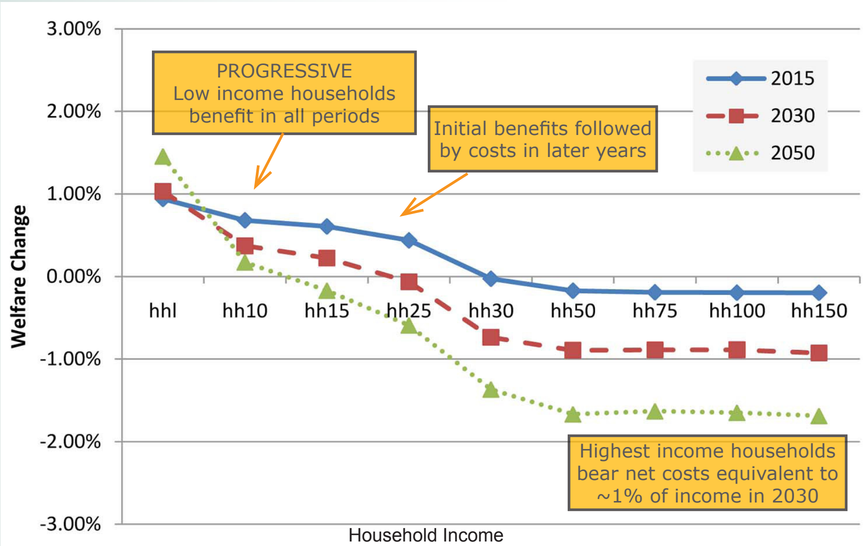
The impacts of the additional costs would also be mitigated by mechanisms built into the bills. Among these provisions is one that would distribute dividends to households or regions likely to feel the greatest impacts of the carbon charges. "One way or the other," Reilly says, "all of the proposals actually benefit low-income households, because the allowance allocation they receive is greater than their increases in energy costs and effects on income."

Laurie Johnson, chief economist for the Natural Resources Defense Council, says that "it's not at all surprising that the authors find the legislation [in its various specific forms] to be progressive, because some of the proceeds from the sale of pollution permits are redistributed back to households on a per-capita basis."

In fact, she says, if anything, the economic impacts on most people will be even less than this study suggests (or actually beneficial), because it doesn't include the environmental benefits to be gained from the reductions in emissions. "Were these included," she wrote in a blog post about the new findings, "the discussion of 'costs' of climate legislation would likely turn on its head, and instead be about benefits and savings."

The researchers note that their analysis could help fine-tune cap-and-trade proposals: Policymakers, they say, could use the findings to revise legislation and mitigate the negative effects on particular regions or income levels. By using the computer model they developed, Rausch says, it's now possible to take any specific proposal or modification of the existing bills and "run it through the model and see the effects, taking into account all the complex interactions."

Although they have not yet analyzed the scaled-back legislation now being offered in place of cap and trade, Reilly says it contains provisions that would add to energy costs without generating revenue to offset these costs for lower-income households. Thus it might bring higher costs than the original legislation, while achieving much less reduction in emissions.



Welfare Change by Income Group, U.S. Average, under a Targeted Allowance Allocation Scheme (based on the Waxman-Markey or Kerry-Lieberman Proposals)

Report 186: The Future of U.S. Natural Gas Production, Use, and Trade

Gas as a bridge fuel to low-carbon alternatives

In terms of costs and emissions, natural gas lies somewhere between expensive-but-mostly cleaner renewables and other cheap-but-dirty fossil fuels. Natural gas emits CO_2 when burned, but releases fewer greenhouse gas emissions than coal or oil. Though a cleaner alternative, some forms (like shale gas, tight sands, and coal bed methane) have also been historically expensive to recover. However, recent technological advances may make the recovery of deposits once thought to be too expensive to exploit, economic. The Joint Program Report 186 addresses the question: What role might natural gas play in US energy policy in the future?

Using first the Emissions Prediction and Policy Analysis (EPPA) model, and then the US Regional Energy Policy (USREP) model, researchers explored how US gas production, use, price, and trade will be affected in the future by changes in 1) the scale of domestic gas resources, 2) the form of domestic greenhouse gas policies, 3) costs of competing alternatives to gas, and 4) the state of world gas production and trade.

The results of this study were used as inputs in the collaborative MIT study The Future of Natural Gas, in which the Joint Program's Henry Jacoby served as co-chair.

1. Domestic Gas Resources

Global supplies of natural gas resources, and the costs of extracting them, were re-evaluated as inputs to the EPPA model. Supply functions for US conventional gas, shale gas, tight gas, and coal bed methane resources outline the quantity of gas that would be commercial at different extraction cost levels.

This re-evaluation of US gas supply shows that shale gas adds significantly to the US resource base and allows for the production of natural gas to continue increasing into the future. When shale gas resources are included, gas production in the US is expected to rise by 42% by 2050, with gas use increasing by 35%. Exploitation of domestic shale gas would alter the geographical distribution of production and require changes in transportation infrastructure, such as expansion of pipelines out of the South Central region.

2. Greenhouse Gas Policies

Under a "no-new-policy" scenario, US gas use and production is still expected to increase, in large part due to expansion of domestic shale gas production. Electricity generation from natural gas would rise by about 2/3 between 2005 and 2050.

A price-based greenhouse gas emissions policy, in which emissions are reduced 50% below 2005 levels by 2050, would reduce total energy use but favor gas over other fossil fuels. Despite reduced energy demand, US gas production and use is projected to increase, driving coal from the energy mix, until 2040- when increasing CO_2 charges cause them to begin declining. An extended price-based policy, in which emissions are reduced 80% below 2005 levels by 2080, shows gas eventually being priced out of the market as well, to be replaced primarily by nuclear power or other carbon-free technology. The study suggests the need for expansion of nuclear power and CCS technology, to prepare for future replacement of natural gas.

A final scenario considered in the study is a regulatory approach, which entails a 25% renewable electricity standard by 2030 and retiring of coal plants representing 55% of current production by 2050. This policy results in a smaller reduction in demand but a rapid expansion of renewable energy sources in early decades that squeeze out natural gas from the electric sector. However, gas continues to make a major contribution to US energy use across all sectors.

3. Energy Mix

Natural gas competes strongly in the electric sector; because it releases fewer emissions, gas acts as a good substitute for coal. Under a price-based policy, reduced demand outweighs gas's carbon advantage in other sectors and, as CO_2 prices increase, gas is shifted more and more to the electric sector to replace coal. Eventually, natural gas will need to be phased out and replaced by lower CO_2 technologies. But in the near-term, gas can act as a bridge fuel to replace coal.

The study also examines the sensitivity of gas use and production to costs of competing technologies. For example, cheaper CCS technologies, renewables, and nuclear generation cause gas use in the electric sector to increase, decrease, and dramatically decrease, respectively. In other words, under a price-based policy, gas is strongly competitive unless there are cheaper-than-expected competing technologies. Because gas can be used in some form in many sectors, the introduction of a lower-cost competitor in one sector allows for the cheapest portion of the freed-up supply to be used by other sectors.

4. World Production and Trade

Should a global gas market emerge, the US would become more dependent on gas imports once cheaper domestic shale gas has been extracted, likely by 2030-2040. Development of an efficient international market would benefit the US economically, but the availability of less expensive LNG options would limit development of domestic resources. Despite rising gas use and domestic shale deposits, imports may increase to 50% of demand by 2050. In addition to importing gas from Canada, the US would likely expand LNG facilities to accommodate imports from the Middle East and Russia, as these countries have vast gas reserves that can be exploited at low costs.

To summarize, the study found that natural gas has a highly favorable outlook in the next several decades. US production and use is projected to rise without new greenhouse gas policies. Price-based policies favor natural gas over other fossil fuels and the share of gas in the energy mix would increase despite reduced energy demand and reduced total gas usage. Gas competes most strongly in the electric sector and can act, under climate policies, as a bridge fuel between coal and lower-CO_2 energy sources. If a world market for gas should develop, increasing imports of LNG would be economically efficient, increasing total gas use, but limiting development of those domestic gas resources that are less competitive with imports.

Graphic: Christine Daniloff

On June 25, 2010 the interim report of MIT's The Future of Natural Gas was publicly released at the National Press Club in Washington, DC by the study co-chairs – Professor Henry Jacoby, co-director of the MIT Joint Program on the Science and Policy of Global Change, Mr. Tony Meggs, MIT Visiting Engineer, and Professor Ernest J. Moniz, Director of the MIT Energy Initiative (MITEI). To download the interim report, go to: http://web.mit.edu/mitei/research/studies/report-natural-gas.pdf

MIT releases major report: The Future of Natural Gas

Study finds significant potential to displace coal, reducing greenhouse gas emissions

Natural gas will play a leading role in reducing greenhouse-gas emissions over the next several decades, largely by replacing older, inefficient coal plants with highly efficient combined-cycle gas generation. That's the conclusion reached by a comprehensive study of the future of natural gas conducted by an MIT study group comprised of 30 MIT faculty members, researchers, and graduate students. The findings, summarized in an 83-page report, were presented to lawmakers and senior administration officials this week in Washington.

The two-year study, managed by the MIT Energy Initiative (MITEI), examined the scale of U.S. natural gas reserves and the potential of this fuel to reduce greenhouse-gas emissions. Based on the work of the multidisciplinary team, with advice from a board of 16 leaders from industry, government and environmental groups, the report examines the future of natural gas through 2050 from the perspectives of technology, economics, politics, national security and the environment.

"Much has been said about natural gas as a bridge to a low-carbon future, with little underlying analysis to back up this contention. The analysis in this study provides the confirmation — natural gas truly is a bridge to a low-carbon future," said MITEI Director Ernest J. Moniz in introducing the report.

Moniz further noted, "In the very long run, very tight carbon constraints will likely phase out natural gas power generation in favor of zero-carbon or extremely lowcarbon energy sources such as renewables, nuclear power or natural gas and coal with carbon capture and storage. For the next several decades, however, natural gas will play a crucial role in enabling very substantial reductions in carbon emissions."

* * *

MIT News Office, June 25, 2010
For the full press release, please see: http://web.mit.edu/press/2010/natural-gas

On September 16, 2010 a summary report of MIT's The Future of the Nuclear Fuel Cycle was publicly released at the Center for Strategic and International Studies in Washington, DC. Joint Program Executive Director John Parsons was a member of the Fuel Cycle study group that helped produce this summary report. The final report is not yet available, but will be released later in this year. To download the summary report, go to: http://web.mit.edu/mitei/docs/spotlights/nuclear-fuel-cycle.pdf

Nuclear-fuel report challenges key assumptions

MIT study finds no shortage of uranium for nuclear energy for decades, but more research is needed to develop improved fuel-cycle options.

David Chandler, MIT News Office

Uranium supplies will not limit the expansion of nuclear power in the U.S. or around the world for the foreseeable future, according to a major new interdisciplinary study produced under the auspices of the MIT Energy Initiative.

The study challenges conventional assumptions about nuclear energy. It suggests that nuclear power using today's reactor technology with a once-through fuel cycle can play a significant part in displacing the world's carbon-emitting fossil-fuel plants, and thus help to reduce the potential for global climate change. But determining the best fuel cycle for the next generation of nuclear power plants will require more research, the report concludes.

The report focuses on what is known as the "nuclear fuel cycle" — a concept that encompasses both the kind of fuel used to power a reactor (currently, most of the world's reactors run on mined uranium that has been enriched, while a few run on plutonium) and what happens to the fuel after it has been used (either stored on site or disposed of underground — a "once-through" cycle — or reprocessed to yield new reactor fuel).

Ernest J. Moniz, director of the MIT Energy Initiative and co-chair of the new study, says the report's conclusion that uranium supplies will not limit growth of the industry runs contrary to the view that had prevailed for decades — one that guided decisions about which technologies were viable. "The failure to understand the extent of the uranium resource was a very big deal" for determining which fuel cycles were developed and the schedule of their development, he says.

* * *

MIT News Office, September 16, 2010
For the full press release, please see: http://web.mit.edu/newsoffice/2010/nuclear-report-0916.html

Report 187: Combining a Renewable Portfolio Standard with a Cap-and-Trade Policy: A General Equilibrium Analysis

Study shows that two climate policies are not always better than one

Can combining different climate policies reduce emissions more efficiently? A new report released by the Joint Program looks at the interaction between two instruments for limiting greenhouse gas emissions: cap-and-trade policy and renewable portfolio standards (RPS).

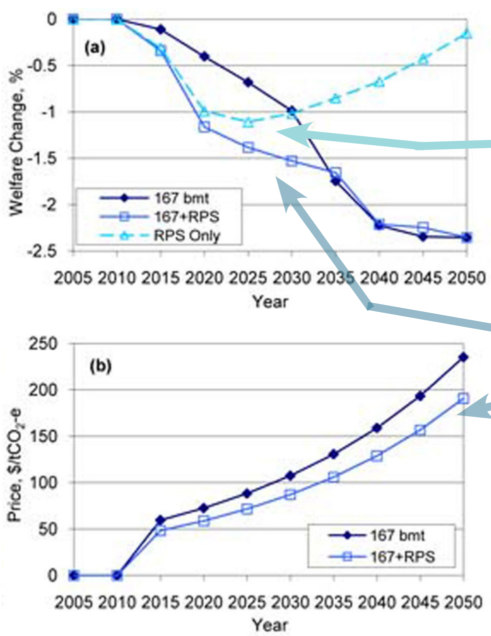
Cap-and-trade is considered by many economists to be the most cost-effective means of reducing greenhouse gases. In proposed legislation, cap-and-trade is often combined with regulatory instruments like RPSs, which stipulate that a minimum amount of electricity come from renewable energy sources.

Using a computable general equilibrium model called the MIT Emissions Prediction and Policy Analysis (EPPA) model, researchers investigated the effects of a cap-and-trade policy combined with a RPS on welfare costs and price of carbon dioxide equivalent (CO_2-e). The model incorporated new inputs, including intermittent renewable energy sources with a backup (e.g. wind with gas backup) and the trading of renewable electricity credits (RECs).

The study found that combining increasingly stringent RPSs with a cap-and-trade policy would result in decreasing CO_2-e prices and substantial rises in welfare costs (total cost of the policies).

A key problem with RPSs is that they require the use of renewable technology, regardless of cost. Because they pick technology "winners" rather than investing in the most cost-efficient options, RPSs can be very costly, particularly if renewable technology proves to be expensive.

For the scenarios considered in the new report, renewable portfolio standards are particularly expensive in early years as renewable technology infrastructure is developed.



A RPS policy without cap-and-trade has greater welfare losses in the short term and does not significantly reduce emissions

Though a combined RPS and cap-and-trade policy results in lower CO_2-e prices, it also results in greater welfare losses than a cap-and-trade policy on its own

The impact of different policies (cap-and-trade, cap-and-trade plus RPS, and RPS only) on a) welfare change and b) CO_2-e price.

A RPS requiring 20% renewables by 2020 increases the net present value of welfare costs by 25% if added to a cap-and-trade policy (80% reduction from 1990 levels by 2050). After 2030, expanding renewable energy becomes more cost-effective, since infrastructure already exists, there are fewer adjustment costs, and other options such as replacing coal with gas are no longer effective given the emissions reduction required.

Though the price of CO_2-e does decrease under RPSs, this is a misleading indicator of the true cost of climate policy. As the cost of renewable technology increases, CO_2-e price would remain nearly the same but overall welfare costs would greatly increase. This means that the lower CO_2-e prices that occur with increasing RPSs effectively hide the true, economy-wide cost of the climate policy.

Even if renewables turn out to be less expensive than represented, a cap-and-trade system would integrate this technology sooner and at higher levels, making a RPS largely redundant.

Thus, there is little reason to recommend a policy that combines RPS and cap-and-trade. Furthermore, if the primary goal is to lower carbon emissions, a RPS alone (without cap-and-trade) risks being a relatively expensive and ineffective way to reach significant reductions.

Report 188: On the Correlation between Forcing and Climate Sensitivity

A Mystery in the Model

A new report was released by the MIT Joint Program on the Science and Policy of Global Change that provides some clues to a mystery in climate modeling.

Several researchers had previously recognized a correlation between radiative forcing and climate sensitivity in the simulations with climate models, but different studies disagreed on the nature of the correlation. Could the correlation be an artifact of differences in the way that models treat aerosols? Or is there a real physical link between climate sensitivity and the radiative forcing that results from increasing concentrations of atmospheric CO_2 and other forcing agents?

The MIT study found that there is no physically based correlation between climate sensitivity and the radiative forcing associated with CO_2 increases, and only a weak correlation between climate sensitivity and the radiative forcing associated with increases in sulfate aerosols, which is explained by differences in cloud cover between the model versions. The correlation found in the simulations with different climate models is a result of the differences in the way models treat forcing agents, primarily aerosols.

To better understand this mystery, and the results of this study, let's start with some definitions.

Radiative forcing

is the effect that a given factor has on changing the Earth's energy balance. In other words, it is the ability of a given factor to change the balance between the amount of energy coming in to Earth and the amount of energy leaving Earth. Therefore, it is an indicator of how important that given factor is in affecting climate change. When different greenhouse gases or aerosols (particles suspended in the air) are emitted into the atmosphere, they alter (or "force") the balance of Earth's incoming and outgoing energy in different ways.

Climate sensitivity

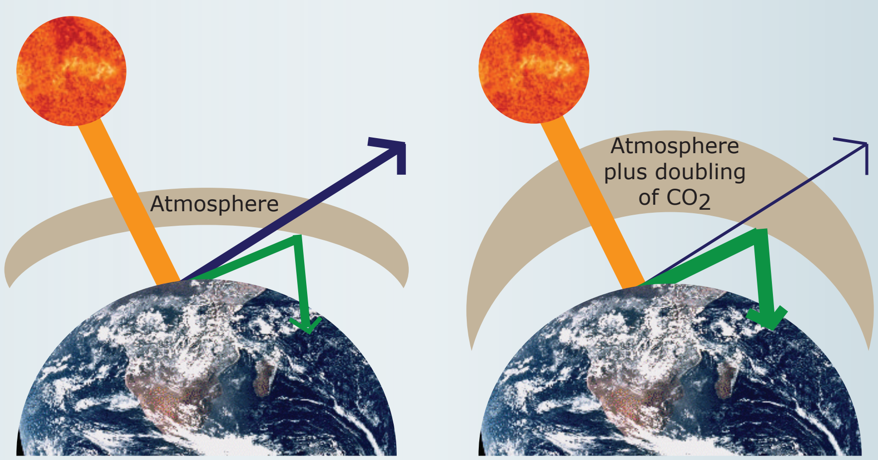
refers to the relationship between a change in the atmospheric concentration of greenhouse gases and the resulting change in temperature. It is a measurement of the change in temperature caused by a change in radiative forcing (or Earth's energy balance). A common measure of climate sensitivity asks the question: what would the resulting temperature change be if the concentration of CO_2 in the atmosphere doubled from pre-industrial times? Thus climate sensitivity is a way to measure how responsive (how "sensitive") the climate system is to changes in greenhouse gas concentrations. Variation in estimates of climate sensitivity comes from uncertainty in feedback effects.

So a change in the atmospheric concentration of CO_2, for example, causes a certain change in total radiative forcing, or the Earth's energy balance, based on the specific radiative forcing of CO_2. And a change in the Earth's energy balance causes a certain change in temperature, based on climate sensitivity.

> The question is whether there is a dependency between climate sensitivity and total radiative forcing, either because of CO_2 forcing or sulfate aerosol forcing, or whether the observed correlation is just a result of differences in the models.

Earth's Energy Balance

(1) The change in radiative forcing, associated with increased CO_2 in the diagram below, changes Earth's energy balance



Energy that leaves Earth + Energy trapped / Energy from the sun

Energy that leaves Earth + **Energy trapped** / **Energy from the sun**

(2) The temperature change, in response to the change in energy balance, is determined by climate sensitivity

2 x CO_2 in the atmosphere = ? degrees change in temperature

In this study, the radiative forcing caused by a doubling of the concentration of CO_2 was examined to see if it changed with different values of climate sensitivity, which would suggest a real physical link between CO_2 forcing and sensitivity. The study also examines the radiative forcing caused by increases in sulfate aerosols.

The researchers ran multiple simulations on three versions of the Community Atmospheric Model with different climate sensitivities: the first where a doubling of CO_2 concentrations results in a change of temperature of 2.0°C, the second 2.6°C, and the third 2.9°C. Though the climate sensitivities changed, the treatment of forcing agents was kept identical in all three models. In this way, any differences in the total radiative forcing, caused by either CO_2 or sulfate aerosols, could be attributed to the different values of climate sensitivity used in the model.

As noted above, the study found no significant difference in the radiative forcing associated with CO_2 increases for the three different climate sensitivities. Thus, there is no evidence for a real physical dependency between the radiative forcing from CO_2 doubling and climate sensitivity.

The study found only slight differences in the radiative forcing associated with increases in sulfate aerosols, but these differences are attributed to differences in cloud cover between the three versions of the model. Therefore, the study concludes that the mystery correlation is a reflection of how different models treat forcing agents, primarily aerosols, differently.

Understanding the reason for the observed correlation will help climate modelers recognize uncertainty in aerosol forcing and take this correlation into account when projecting future climate change.

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