HEARING ON CLIMATE CHANGE: COSTS OF INACTION

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND AIR QUALITY

OF THE

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WITNESSES

HEARING ON CLIMATE CHANGE: COSTS OF INACTION

THURSDAY, JUNE 26, 2008

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND AIR QUALITY,
COMMITTEE ON ENERGY AND COMMERCE,
Washington, DC.

The subcommittee met, pursuant to call, at 10:04 a.m., in room 2123 of the Rayburn House Office Building, Hon. Rick Boucher (chairman) presiding.

Members present: Representatives Boucher, Melancon, Barrow, Markey, Harman, Gonzalez, Inslee, Baldwin, Matheson, Matsui, Dingell (ex officio), Upton, Whitfield, Shimkus, Blunt, Walden, Burgess, Blackburn, and Barton (ex officio).

Staff present: Lorie Schmidt, Laura Vaught, Bruce Harris, Chris Treanor, Rachel Bleshman, Alex Haurek, Erin Bzymek, David McCarthy, Amanda Mertens-Campbell, Andrea Spring, and Garrett Golding.

OPENING STATEMENT OF HON. RICK BOUCHER, A REPRESENTATIVE IN CONGRESS FROM THE COMMONWEALTH OF VIRGINIA

Mr. BOUCHER. The subcommittee will come to order. Much has been said about the costs that are associated with mandatory federal actions to reduce greenhouse gas emissions. In fact, concerns about the costs of regulation were raised during this subcommittee's hearing 1 week ago today which focused on the various cap-and-trade measures that are now pending in both houses of Congress. While the costs of action are relevant concerns, underpinning our goal of producing a regulatory program that confers the maximum environmental benefit at the least cost to society, we should also recognize that failing to regulate emissions also carries a cost, and in fact, it is a quite substantial one. The avoidance of enacting a mandatory greenhouse gas control program does not mean that we avoid cost, and the cost of inaction may well be greater than the cost of acting.

Today, we focus on the cost of failing to act on the effect of climate change for our national security, for land and water resources, for agriculture, and for biodiversity. Our discussions today are guided by three reports, which evaluate various consequences of Congress failing to act.

We are pleased to have as a witness this morning Lord Nicholas Stern, author of "Stern Review: the Economics of Climate Change," a thorough analysis of the costs of inaction, which was prepared at the request of the government of the United Kingdom. Lord Stern concluded that while the cost of reducing emissions can be limited to approximately one percent of global gross domestic product, the cost of not acting would equate to as much as 5 percent of global gross domestic product. While his conclusions are not without controversy, his report is authoritatively cited in the United Kingdom and elsewhere, and we are pleased to welcome Lord Stern as our first witness this morning.

Another report which is the subject of today's hearing is the National Security and the Threat of Climate Change, prepared by the Military Advisory Board, an entity that is comprised of retired United States admirals and generals. That report notes that while there is some disagreement about the extent of future effects that are due to climate change, risks are such that action is justified, and that projected, uncontrolled climate change poses a serious threat to national security.

We will also receive a review of the United States Climate Change Science Program Agricultural Report, which assessed the effects of climate change on U.S. land and water resources, on agriculture and on biodiversity. This report finds that it is very likely that climate change is already affecting United States natural resources and will continue to have significant effects over the next decades.

An exact estimation of the cost which will be incurred as a result of unmitigated climate change is difficult to make, and efforts to do so, such as the Stern Review, are often subject to some extent of controversy because of the economic and scientific assumptions that necessarily must be made. While these predictions are difficult to make, the reports that we examine today and other reports in the field leave very little doubt that the effects of climate change will result in cost. As sea levels rise, as storms become more severe, as ecosystems are altered and drought and other climate effects occur, it is inevitable that there will be a cost of our responding. And examination of these effects is essential to our effort to achieve a balance in the legislation that this subcommittee will draft, between environmental benefit and the cost of conferring that benefit.

We will turn to our first witness shortly, but prior to that, I want to recognize other members for their statements, and at this time, the gentleman from Michigan, Mr. Upton, the ranking member of the subcommittee, is recognized for 5 minutes.

OPENING STATEMENT OF HON. FRED UPTON, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF MICHIGAN

Mr. UPTON. Well, thank you Mr. Chairman, and I want to start off by conceding that I believe there is a cost for inaction. There is, however, also a cost for certain actions. Not every policy action will yield the same results. In every decision we make here in the Congress, we must properly weigh the costs versus the benefits.

The underlying purpose of the hearing today is to demonstrate that the cost of inaction is so high that even the most costly and least action, cap and trade, perhaps, is worthwhile, and some may disagree. Given the complexities involved and the many moving parts involving far more than just science and economics, accurately determining the cost of inaction is more difficult to predict than the cost of various actions. In fact, a large number of highly regarded economists have criticized the Stern Review on the Economics of Climate Change as perhaps being outside of the mainstream. One noted Harvard economist wrote that the Stern Review consistently leans towards assumptions and formulations that emphasize optimistically low expected costs of mitigation, and pessimistically high expected damages from warming. Stern's analysis sees increasing hurricane damage in the U.S. as a costly result of global warming; yet, according to NOAA's physical fluid dynamics laboratory, findings do not support the notion that human-induced climate change is causing an increase in the number of hurricanes. While I have a great deal of respect, certainly, for Sir Nicholas Stern, I have doubts about the accuracy of the report, based on some scientific and economic grounds.

The British-sponsored fast-track assessment of global climate change, a major input in the Stern Review, indicates that through the year 2100, non-climate-related threats to human health and welfare will greatly overshadow climate change, so for the next 100 years or so, climate change will not be the greatest threat facing our planet. For arguments' sake, if we were to halt climate change by 2085, we could reduce mortality from hunger, malaria, and costal flooding by 4 to 10 percent. However, if we are to focus specifically and directly on reducing those risks, I believe that mortality could be cut by as much as 50 to 75 percent at a fraction of the cost of the approach aimed at reducing greenhouse gasses.

As one who believes that climate change must be dealt with on a global scale, I have advocated no-regrets policies that will achieve the same, if not better results than arbitrary cap-and-trade, at perhaps a fraction of the cost. In fact, there are policy options available that would have a net economic and societal benefit. We have lost too many jobs already, certainly in my State of Michigan, and the energy costs have already reached alarming levels, and we are all paying the costs. Just ask Al Gore what his monthly power bill is now. We can pursue options that won't make matters worse.

At last week's hearing I outlined five straightforward principals, climate change policy that it must adhere to, and they are worth repeating today: one, provide a tangible environmental benefit to the American people; two, advance technology to provide the opportunity for export; three, protect American jobs; four, strengthen U.S. energy security; and five, require global participation. These principals deal with the issues of cost versus benefit, the cost of action, as well as the cost of inaction. Any action on climate change must achieve meaningful environmental benefits and should rely on technological advancements and consumer choices rather than, perhaps, mandates and bureaucracy. We won't need costly mandates if we invest in clean-coal technology, remove the regulatory barriers for nuclear power, and provide tax incentives for renewable power. We won't need the developing world to remain in the stone age if we export American technology, and we won't need to lose hundreds of thousands, if not millions, of jobs if we help our energy-intensive industries and domestics and domestic auto manufacturers with their R&D investments. Climate change is a global problem, and it requires a global solution. Without joint international action, jobs and emissions will simply shift overseas to countries that require few, if any, environmental protections, harming the global environment as well as the United States economy.

The sky, I don't think, is falling, but we can work together in a thoughtful way to collectively ensure our economic energy and environmental security. I yield back my time.

Mr. BOUCHER. Thank you very much, Mr. Upton. The gentlelady from Wisconsin, Ms. Baldwin, is recognized for 5 minutes.

OPENING STATEMENT OF HON. TAMMY BALDWIN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF WISCONSIN

Ms. BALDWIN. Thank you, Mr. Chairman. I am delighted to have Lord Stern and our subsequent panel of expert witnesses before us today. It is your work and your studies that have framed the discussion on climate change, and you have conveyed a message of urgency on us to act to lower greenhouse gas emissions in a quick and meaningful manner, and it is now up to us to heed your advice and rise to this challenge.

We know that climate change comes with a very large price tag, and costs are not just economic. Our emissions have also put our environment, social structure, and national security at risk, and according to the analysis, if we fail to act comprehensively, the impacts will be felt through the loss of human lives and health, species extinction, the loss of ecosystems, and social conflict.

As Members of Congress, especially as member of the People's House, we are generally prone to design and pass legislation that will provide immediate or near-term relief to our constituents. It is seemingly a challenge for us to even fathom enacting consequential legislation that may raise near-term costs with benefits not reaped for a generation or more, benefits that some of us may not live to see. Yet this is the predicament in which we now find ourselves. Do we make the investments now to avoid the worst impacts of climate change? According to Lord Nicholas Stern, the cost of acting today is about 1 percent of global GDP each year. Or do we wait, leave this issue for future generations, and watch the costs and risks rise at a rate of up to 20 percent of global GDP per year?

I am of the opinion that the risks are far too great for us to fail to act in the very near term. Just last week, the U.S. Climate Change Program released a report that provides the first comprehensive analysis of observed and projected changes in weather and climate extremes in North America. Among the extremes predicted are more frequent and intense heavy downpours. The report concludes that the increases in precipitation are consistent with the observed increases in atmospheric water vapor, which has been linked to human-induced increases in greenhouse gases.

I have seen firsthand the intense rain, flooding, and devastation that people in the district that I represent in Wisconsin, and across the Midwest, are experiencing as a result of intense rainfall this month. We lost homes, businesses, and farmland, not to mention millions of dollars in lost productivity. I can only hope that we will do everything in our power to ensure that these storms do not become the norm in the future.

Mr. Chairman, the scientific community has come together on this issue, and now it is up to us, all of us, to educate the cynics and the naysayers that climate change is real. It threatens our economy, our environment, and our national security, and we will pay a much greater cost in the future if we fail to act. Thank you, Mr. Chairman, again, for holding this very important hearing, and I yield back the balance of my time.

Mr. BOUCHER. Thank you very much, Ms. Baldwin. The gentleman from Kentucky, Mr. Whitfield, is recognized for 5 minutes.

OPENING STATEMENT OF HON. ED WHITFIELD, A REPRESENTATIVE IN CONGRESS FROM THE COMMONWEALTH OF KENTUCKY

Mr. WHITFIELD. Well, Chairman Boucher, thank you very much for conducting this important hearing on Climate Change: the Cost of Inaction. Obviously, this subject matter is vitally important to not only our country but the entire world.

I would say that cap-and-trade systems have come into vogue because many people say they are politically palatable more than imposing carbon taxes. I am pleased to say that Chairman Boucher, Ranking Member Barton, Mr. Upton, Mr. Shimkus, and I have introduced bipartisan legislation to create a fund for research, development, and deployment of the carbon capture-and-store technology that is so vitally important to help solve this problem. These types of initiative, I believe, will put our country on the road to reducing carbon emissions, rather than implementing overly ambitious, expensive, and maybe unworkable proposals that could damage our economy and do very little to reduce carbon emissions globally.

I am delighted that Lord Stern is with us today, because I was reading an article in the New York Times just a couple of days ago, and the whole article was featured on the carbon markets in Europe, and it says Europe has had trouble handling its carbon market. And it specifically pointed out that CO_2 emissions have risen each year since the European cap-and-trade system went into effect, and that there are major problems that they are still struggling with in this issue in Europe. And one of the major concerns that I have about adoption of a strong cap-and-trade system to set progressive targets to reduce carbon dioxide and greenhouse gas emissions here in the U.S. is we don't have the technology available to meet it, and so that presents a major problem.

So I know that many people refer to the cap-and-trade system that was implemented to deal with acid rain, and that was and has been successful because the technology was available to reduce NO_x and SO_x emissions.

And then another major concern that I have when we talk about cap-and-trade systems is that there seems to be a bias by many people that coal can no longer be an important part of the United States energy picture. And I would remind everyone that coal still produces 51 to 52 percent of all of the electricity produced in America, and I think it is unrealistic to think that we can go to alternative energy sources without dramatically increasing the cost of electricity, which increases the cost of production, which makes us less competitive with other economies around the world and ultimately can damage our economy.

So we have this important balancing act that must be done, and these types of hearings will help us focus on those issues and hopefully make the right decision. And I yield back the balance of my time.

Mr. BOUCHER. Thank you, Mr. Whitfield. The gentleman from Michigan, Mr. Dingell, the Chairman of the full Energy and Commerce Committee, is recognized for 5 minutes.

OPENING STATEMENT OF HON. JOHN D. DINGELL, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF MICHIGAN

The CHAIRMAN. Mr. Chairman, thank you for holding this hearing today. It is a very important one, and your leadership in the matter of global warming and other things under the jurisdiction of this committee has been exemplary, and I want to commend you and thank you.

The hearing today addresses a very important topic, the risks we face if the world fails to address climate change. And I would begin my statement by observing that we will move forward as fast as we can in achieving good legislation, which will address the concerns and the problems of this nation and the world in a responsible, thorough, and thoughtful fashion.

At last week's hearing, and in the Senate, we have heard a lot about how much reducing greenhouse gas emissions is going to cost us, including projected changes in gas prices, electricity rates, and gross domestic product in 2050. It is undoubtedly true that there will be costs associated with this. It is also obviously true that there will be costs associated with inaction, and so that leads us to the point of finding what is the best way to address this concern, and I intend to see to it that we do so, but we do so in a vigorous fashion.

The basic point my colleagues are making is correct and one that we must not lose sight of: reducing greenhouse emissions will cost us money. But the projections of the costs of climate change programs as observed here today are only half the story. We must understand the costs of inaction, how much we will have to spend if we refuse to reduce greenhouse gas emissions. That is the important focus of today's hearing. It is also an unsaid and unstated matter that we have to address this problem because of the cost of imported oil and the simple fact that this country can no longer have that particular expenditure.

Understanding the costs of both action and inaction is necessary for us to design fair and reasonable climate legislation. One economist suggests that all we have to do is set up a program where the marginal costs of actions equal the marginal costs of inaction; following a simple, mathematical formula, we will then solve our problems. I wish it were so, but I don't believe it will be that easy. First we cannot easily put a dollar value on many of the costs of inaction, such as the loss of wildlife habitat, species extinction, loss of quality of life. Second, there is a strong scientific consensus that human-caused greenhouse gas emissions are warming the planet. Scientists cannot tell us precisely what will happen at different greenhouse gas levels, such as how much more people will suffer or how many more people will lose homes and farms to flooding.

It is said that we need to understand that the best they can do is to tell us what the risks might be and the possibilities or probabilities that physical changes will occur, and the costs that we will incur to address those changes.

Third, the global warming problem and climate change means that we will need to act in concert with other countries. The fact that we lack certainty and precision about future costs of climate change does not mean we should not act. When faced with even low risk of a catastrophic event, we regularly buy insurance policies to avoid, cover, or reduce those risks. Reducing greenhouse gas emissions could be thought of as protecting against risk of this magnitude in a similar and thoughtful way.

I would prefer to legislate with more certainty from the scientists who tell about the dangers we face in the future, but unhappily we do not have that luxury. Scientists are already observing effects now of climate change. Our witnesses today will tell us that our failure to act could put the planet and our country at risk for even bigger and graver consequences. Today's hearing is going to help us understand the potential severity of those consequences. Thank you, Mr. Chairman, and I yield back the balance of my time.

Mr. BOUCHER. Thank you very much, Mr. Dingell. I understand that Mr. Markey intends to waive his opening statement, and instead have 3 minutes added to his question time for the first witness. I am assuming that is correct.

Mr. MARKEY. I request that. Thank you.

Mr. BOUCHER. We will note the gentleman's waiver. Now, now, now. I am going to recognize somebody else while I still have a measure of control here. The gentleman from Oregon, Mr. Walden, is recognized for 5 minutes.

OPENING STATEMENT OF HON. GREG WALDEN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF OREGON

Mr. WALDEN. Thank you very much, Mr. Chairman. I appreciate this hearing and the others that you have held. They have been most informative with really expert witness, and while I have to step out for another meeting here in a few minutes, I do have the testimony and plan to return.

Obviously, we have heard a lot about climate change. And Lord Stern, we are delighted to have you here, and I know your report has been the basis upon which a lot has been written, both pro and con, and that is the way it is with any issue of this magnitude and certainly scientists and economists are disagreeing on the magnitude of this issue.

I represent a district of 70,000 square miles. We have home of ten national forests, and my passion has been the role that forestry can play, in a very positive sense, in dealing with greenhouse gas emissions, and there are studies that show actively managed forests could lead to 50- to 60-percent reduction in wildfires, which equates to about a million tons of greenhouse gas annually. It could be reduced in California alone, for example. Even though I am from Oregon, there was a report done by Finney and others that indicates that in California alone, if you had properly managed forests, you could reduce greenhouse gas emissions by a million tons a year. Managed forests sequester carbon at 1.25 tons per acre per year, and yet our federal forests sequester less than half a ton per acre per year. If you use a ton of bone-dry biomass in a biomass power plant to generate electricity as opposed to natural gas, you can reduce a one-ton net reduction in greenhouse gas, compared to natural gas, for every ton.

And so I think there is an enormous opportunity here to review federal policies in this country as they relate to proper managements of forests. I have met with the U.S. Forest Service on multiple occasions. They have done a long-term look at climate change and its effects on forestry and indicate to me that the forest cannot keep pace with the change in temperature, in terms of northward migration. And as a result, we will have more drought, more bug infestation, more disease, overstocked stands, and as a result, higher fire ratios. In fact, in the last couple of years, we have set records for the number of lands burned, not all of it forests, some of it grasslands. I think it is upwards of 9 million acres a year. Forty-seven percent of the Forest Service's budget is now spent for fighting forest fires.

And so I conclude with this comment that those who argue for change in other sectors of federal law cannot any longer ignore the need to change forest-management law so that we can more aggressively get in, get these stands back in balance, so that when fire occurs, it burns naturally and actually can be good for the environment, as opposed to these unnatural, catastrophic, high-emission releasing fires that are very costly to society and to the climate. And I hope at some point this committee will be able to look at those issues as well. Lord Stern, thank you for being here. Mr. Chairman, my time has expired, and I appreciate the opportunity to be here.

Mr. BOUCHER. Thank you very much, Mr. Walden. The gentlelady from California, Ms. Matsui, is recognized for 3 minutes.

OPENING STATEMENT OF HON. DORIS MATSUI, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Ms. MATSUI. Thank you, Mr. Chairman. I am very pleased to be here today, and thank you for calling a hearing on such an important issue. I would also like to thank today's panelists for coming today to share their expertise and add to our understanding of the risk and potential cost of climate change.

All of us here today represent different areas of the country with different climates. We have seen the very impact climate change is having on our diverse landscapes, and the threat of new challenges and dangers if this issue is left unaddressed. My district of Sacramento, California exhibits many of the risks we face. We are surrounded by ecosystems that are already beginning to see significant changes. Sitting at the confluence of two great rivers, Sacramento is considered to have the highest flood risk of any major metropolitan city in the United States. Over 500,000 people, 110,000 structures, the capital of the State of California, and up to $58 billion are at risk. Rising temperatures could mean earlier and more rapid Sierra snowmelt, yielding disastrous consequences. Earlier snowmelt and varying rainfall patterns may also lead to serious drought and water shortages, already a constant worry in my State. Currently, California is rationing water, and farmers are losing their crops. We simply can't afford to see the Western United States with even less water. Wildfires, heat waves, the spread of tropical disease, and rising sea levels can also affect the future of my constituents, their children and grandchildren.

We must take into account the cost of any legislation that would touch so many aspects of our country and our economy, but we can't get stuck on the challenges; we must find the ways to build consensus. We heard last week about some of the possible costs of potential legislation, but it is clear that if we fail to act, the cost to our country, economy, and environment will reach far beyond just the monetary. The fact is that inaction is not an option. Investing our time and resources now will mean saving our children and grandchildren much greater costs in the future.

Mr. Chairman, I thank you for your leadership and your commitment to these issues, and I yield back the balance of my time.

Mr. BOUCHER. Thank you very much, Ms. Matsui. The gentlelady from Tennessee, Ms. Blackburn, is recognized for 3 minutes.

OPENING STATEMENT OF HON. MARSHA BLACKBURN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF TENNESSEE

Ms. BLACKBURN. Thank you, Mr. Chairman. I do want to thank you for holding the hearing, and I want to thank our witnesses who are taking their time to come and testify before us today.

Assuming for the moment that climate change is happening, then the questions before this committee and in this hearing would be what should we do about it, if anything, and what would happen if we fail to act? And climate change activists' basic argument is that current emissions of greenhouse gasses must be reduced by 80 percent. We hear that regularly. They claim that if not, then CO_2 concentration in the atmosphere will cause an increase of 18 degrees Fahrenheit around the world and cause massive floods, famine, hurricanes, and drought that humans have never seen before. Essentially, what they predict is a Doomsday scenario.

But history has quite a different perspective on this. When the Earth was warmer 1,000 years ago, colonies and farms dotted the landscapes in the upper latitudes, but the little ice age occurred, and disaster befell most of those. Then warming ended this ice age, and plants began to grow faster and larger and live in drier climates, providing diversity and enhanced sustainability of animal life. But now, recent data shows that the Earth is cooling significantly and could reverse that stated progress. And if current CO_2 omissions are further reduced, these two factors could lead to another ice age, with drastic reductions in food production. The earth would become a less hospitable and less green planet.

Well, how about that for a Doomsday scenario? Well, Mr. Chairman, I urge my colleagues, I urge all of us to apply a little bit of common sense and not go down expensive and dangerous paths that some would advocate. These globalw arming scares only exacerbate society problems and offer no meaningful solutions. Costly emissions regulations to mitigate global warming will not solve the world's major problem and could actually cause a reverse in the world's temperature gauge. But investment in simple, straightforward solutions, such as clean drinking water, sanitation, basic healthcare can, for a fraction of the cost. These investments will provide a significant economic boost to developing nations, enabling them to adapt to any climate change, whether it is cooling or warming. These countries could flourish without suffering the financial devastation caused by drastic, unwise carbon-reduction policies, promoted through skewed political agenda.

I am looking forward to the discussion today. I do have to step to another meeting, Mr. Chairman. I yield the balance of my time.

Mr. BOUCHER. Thank you very much, Ms. Blackburn. The gentleman from Texas, Mr. Gonzalez, is recognized for 3 minutes. The gentleman waives his opening statement and will have 3 minutes added to his questioning time.

The gentleman from Washington State, Mr. Inslee, is recognized for 3 minutes. He also waives his opening statement.

The gentleman from Louisiana, Mr. Melancon, is recognized for 3 minutes.

OPENING STATEMENT OF HON. CHARLIE MELANCON, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF LOUISIANA

Mr. MELANCON. Thank you, Mr. Chairman. I appreciate you holding this hearing.

I come from south Louisiana, and we have one of the fastest sinking coastlines in the world. When we hear of the cost of climate change legislation, it is easy to forget what it will cost to do nothing. The State of Louisiana has crafted its own impressive master plan to determine how best to protect our communities, and the infrastructure that supplies some 30 percent of oil and gas, flyways for the migratory bird, and the nation's seafood. Our master plan calls for close to $60 billion in hurricane protection and costal restoration. Imagine these costs after decades of inaction, leading to higher sea levels and stronger storms.

We are just one state in one country. The detrimental effect of climate change affects the entire world, oftentimes hitting the poorest countries the hardest. I find it ironic that last night there was a report where the EPA sent to the White House several years back compelling evidence of climate change and global warming and the White House chose to not open the email, but in fact just sat on it. I think that this information could have helped compile additional data which would help give him a better view of what is going on.

I want to thank him for being here today, again, I thank the chairman, and hope that we have some information that can help us ferret through his whole process. Thank you.

Mr. BOUCHER. Thank you, Mr. Melancon. The gentleman from Texas, Mr. Burgess, is recognized for 3 minutes.

OPENING STATEMENT OF HON. MICHAEL C. BURGESS, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF TEXAS

Mr. BURGESS. Thank you, Mr. Chairman, and thank you for holding this hearing. I always appreciate the opportunity to discuss these measures in committee.

Climate Change: the Cost of Inaction: it is a curious title. I used to be a student of medical irony, and now I have branched out into legislative irony. I suppose the title is referring to the inaction of the House of Representatives to come together as a body and make a decision on climate change. The Senate has already produced action, and it seems, at least on this topic, the lower chamber now has become the more deliberative body. In fact, this morning's Washington Post article by Bjorn Lomborg, who has testified before this committee in the past, makes a statement by itself. Lieberman-Warner, by itself, would postpone the temperature increase projected for 2050 by about 2 years.

So I appreciate Chairman Boucher's and Chairman Dingell's sensible approach to this issue. It is thoughtful and warranted, given the complex nature, and the number of affected industries and constituencies involved in this very broad potential action. Ultimately, the question before us, does changing American behavior today save lives in the future, and the word inaction assumes that nothing is being done, but I can tell you that the behavior of the American public in my district is already in motion. In my part of Texas, people are already acting. They are acting like fuel is expensive. They are acting like it is affecting their livelihood. As a result, the American demand for petroleum and petroleum-based products has declined, and emissions in the United States have followed suit. It turns out the economists were right, if you make something more expensive, people will use less of it. I realize the issue of climate change is not that simple, but I also realize that change is painful with many results, some beneficial, and some not, but all consequential.

Now, the Stern Review concludes that taking strong action now to reduce emissions should be viewed as an investment in the future. Page 15: "the benefits of strong, early action on climate change outweigh the cost, with returns not realized for a few decades." We must keep in mind the nature of this problem is long-term, and the hearing today does not address the immediate problems of $4-a-gallon gas and what is happening to our commodity and food prices. But rather, we are here today to find out how we can put money in the bank for the future environmental effects on our planet.

Securing our natural resources and sustaining our environment are not mutually exclusive goals. They are actually mutually dependent. Much of this debate comes down to an issue as to how we discount future harm. In traditional finance, we understand that we would rather owe $100 ten years from now than today because of what is happening to the dollar. Money will be worth less in the future. Lord Stern's analysis refuses to apply this concept to the cost of climate change, and the argument is that harm on future generations should not be discounted. This type of assumption does lead to undervaluation of the costs imposed on our citizens today and risks over-evaluating the benefits gained by future generations, and I hope our discussion this morning will shed some light on that issue.

The hearing will also address the impact of climate change on our national security. Congress must take a hard look at the potential national security risks we face when a struggling government caves under stressors and gives way to authoritarian and radical leadership. That is true not only for energy prices, but it would also be true for prices of food and commodities. It certainly makes no difference if we are more environmentally responsible in the future if we sacrifice our democracy in the process.

I would argue that economies that are strong have done more to protect and are less apt to lead to risky behavior. The preface to the book "Contract with the Earth," written by former Speaker Newt Gingrich, makes the statement "environmental leadership requires the ability to look beyond stereotypes. Environmentalists are not exclusive to one political philosophy. It is quite possible to be a green conservative."

Business is no longer regarded as an adversary to a clean environment. Rather, global industries are the source of brilliant, workable solutions to vexing environmental problems. I do believe in the entrepreneurship, and I do believe in the inventiveness of the American people, and I will yield back the balance of my time and submit the remainder of my statement for the record, Mr. Chairman.

Mr. BOUCHER. Thank you very much, Mr. Burgess. The gentleman from Georgia, Mr. Barrow, is recognized for 3 minutes.

OPENING STATEMENT OF HON. JOHN BARROW, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF GEORGIA

Mr. BARROW. Thank you, Mr. Chairman. I want to thank you for having this hearing, and I want to thank the witnesses for participating in this hearing.

I detect a certain pattern in the almost two dozen hearings this committee has had over the course of this last Congress on this subject. We seem to get the sobering facts as to whether or not there is a problem and whether or not we are contributing to the problem and need to do something about them. And then the folks who know the most about that receded and they start talking about the constituents and the economy at large about what to do about it. Folks tend to fall off the wagon. They tend to get back on some ideas about whether or not there really is a problem or not.

I don't know whether or not short-term swings in our environment with historical record that were characteristic of a carbon balance, a carbon cycle that was in balance for a much longer period of time than those short-term swings, is any indication that things are fine today. I do know this: if the same causes can produce dramatically different results, and each is very disturbing and disquieting, then we ought to be addressing these causes.

And I think I know something else. God Almighty had a carbon sequestration of his own, millions and millions of years of biomass sequestered in the Earth, under his good time, under his good purpose, and we are busting that carbon-sequestration program all to Hell in the last couple of years. We have made dramatic changes in the carbon cycle that we have inherited, and we need to recognize that. It is not the wonderful self-regulating miracle that I was taught in elementary school because we have been doing things to alter that dramatically, and I just hope we will stay focused on the reality that there is a problem, we are contributing to it, the fact that it can produce dramatically different and dramatically unpleasant consequences is no indication that we have a problem on our hands and we have to deal with it.

So Mr. Chairman, thank you for your leadership and keeping us focusing on the mission of this committee and what we are all about here, and with that I yield back the balance of my time.

Mr. BOUCHER. Thank you very much, Mr. Barrow. The gentleman from Texas, Mr. Barton, the ranking member of the full committee is recognized for 5 minutes.

OPENING STATEMENT OF HON. JOE BARTON, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF TEXAS

Mr. BARTON. Thank you, Mr. Chairman. I am delighted to have this hearing. I think it is important to put as many of the facts, or at least what people perceive to be the facts, on the record as possible, and I think you are doing an excellent job of that. I am very pleased to see the witnesses that here today. I have read abstracts and summaries of some of their material and hopefully will have some time to ask some questions, especially our first witness.

I am going to focus on some of the methodology questions, and I still think that you can have an honest debate about the science, and I will have a little bit of that. I tend to agree with what my good friend from Georgia just said. I don't quarrel too much about what he said about the carbon cycle being disrupted. I mean it is obvious if you are bringing hydrocarbons up from down in the Earth that were deposited hundreds of millions of years ago, that you put more carbon into the atmosphere than we would otherwise, and that is a fact. You have got to admit that. I think you can debate the impact of that.

So I am glad to have witnesses. I am glad to have some of them talk about their methodology and the science and the consequences. I think we will have a good hearing, and it will continue to build a record that this committee is noted for doing over the years: let us get the information before we decide on the solution. With that, I yield back.

Mr. BOUCHER. Thank you very much, Mr. Barton. The gentlelady from California, Ms. Harman, is recognized for 3 minutes.

OPENING STATEMENT OF HON. JANE HARMAN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Ms. HARMAN. Thank you, Mr. Chairman, and welcome to our witnesses. I am pleased to participate in yet another careful learning experience on this subcommittee. It is important that we have as much information as possible before we go forward. In that connection, I want to commend Mr. Burgess for his opening comments, and I look forward to reading the rest of them that he inserted in the record, because I think he pulled together a lot of material that this subcommittee needs to think about.

An area he mentioned that I am most keenly interested in, which is not in the sweet spot of our jurisdiction, but nonetheless a critical issue for us as Members of Congress, is the national security implications of climate change. Yesterday, the House Intelligence Committee, on which I no longer serve—I did serve there for 8 years—received a National Intelligence Estimate on the relationship of climate change and national security. It is a very important subject. Careful work is finally being done. There is absolutely no question of the effect on immigration and on food and on stability of governments caused by dramatic climate change. We need to learn more about it, and at least to this member, we need to act as promptly as we can, responsibly, on this issue, because destabilized governments and massive famine and huge changes in immigration patterns are bad for our short-term, let alone longer-term security.

So I appreciate the fact that that is part of this conversation. I also want to say that a witness on the next panel, Sherri Goodman, from the executive general panel—she has got a lot of different titles in this memo that I am reading—but at any rate, connected to CNA, is someone I have known for a long time, and I think she brings great expertise, and I think our subcommittee will benefit from her testimony.

And once again, Mr. Chairman, this is an activity we do need to explore in this committee. It gives us a fuller picture of the context in which we legislate. I believe we can add some real value. I believe that the bipartisan tradition of this subcommittee will help us add value. And just based on the opening comments this morning, there are some very interesting bipartisan comments. Thank you, I yield back.

Mr. BOUCHER. Thank you very much, Ms. Harman. The gentleman from Illinois, Mr. Shimkus, is recognized for 3 minutes.

OPENING STATEMENT OF HON. JOHN SHIMKUS, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF ILLINOIS

Mr. SHIMKUS. Thank you, Mr. Chairman. I want to welcome, also, our panelists. This is a great committee, because the members do their homework. They are very diligent, so we are going to ask hard questions, hopefully, and we shall get hard answers back, and I think it will help us through the process. I have great respect for the chairman of this, and the full committee, with their challenging work ahead. I like to keep things light a lot of times, but this is a pretty heavy and a deep subject for many of us.

A big picture, I do feel that there is—I am a Republican, so I am not using an elephant for that—but one of the elephants in the room is there a worldwide movement to have a centralized standard of living around high energy prices and environmental policies? I actually do believe that there are a lot of people who like high energy prices, and I do believe there is a movement to equalize the world standard around living in the same sized homes, driving the same sized cars, consuming the same type of food, and that is really antithetical to the great American mindset of westward expansion, explore discover, work hard, keep the benefits of your home. So there are people who love these high prices, and if they are out there, they are going to love even higher prices. We have established in this committee that climate change legislation will increase costs. This is looking at the other end of the debate. But we have established that at the last hearing we had. The first panel, I asked everybody on liquid fuels, and they all said, yes, higher costs; electricity generation, they all concurred, higher costs. The cost on this end of what it does to the poor in the rural areas of the world is the cost-benefit analysis that we are going to have to discuss and work through.

I tend to be a promoter of the industrial revolution, the great benefits, and how it created a great middle class. In fact, Chairman Boucher and I sat across the table with a major Chinese official. He was asked twice, would you ever go into a climate change agreement, and they said no. And their response was you had your chance to modernize and develop a middle class using fossil fuels. Now it is ours. That type of mindset, no matter what we do in the industrialized West will never fix and cap carbon, so that is all part of the cost-benefit analysis, for the small, the poor, the middle class, rural American, and climate change will be devastating to them.

Mr. Chairman, I yield back.

Mr. BOUCHER. Thank you very much, Mr. Shimkus. All members have now had an opportunity to make opening statements, and we welcome our first witness to the hearing today.

Lord Nicholas Stern is the IG Patel Professor of Economics and Government at the London School of Economics and Political Science. He serves as an advisor to the United Kingdom government on the economics of climate change and development, and is author of the Stern Review on the Economics of Climate Change. His report has been authoritatively cited in the United Kingdom and elsewhere, and we are very pleased to welcome him this morning and to receive his testimony.

Without objection, your prepared written statement will be made a part of the record, and we would welcome, at this time, your oral summary.

STATEMENT OF LORD NICHOLAS STERN OF BRENTFORD KT, FBA, IG PATEL PROFESSOR OF ECONOMICS AND GOVERNMENT, LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

Mr. STERN. Thank you very much. Chairman Boucher, Ranking Member Upton, distinguished members, thank you very much for the opportunity to discuss with you today. And thank you for the opportunity to listen to your very thoughtful statements at the opening of this discussion.

I speak to you today as an academic, as you have underlined, Mr. Chairman, not as a servant of Her Majesty. I did work for Her Majesty, in particular through her government, as a civil servant, up to about 1 year ago. But I am speaking to you, today, as an individual, Nick Stern, not as a representative of the U.K. in any sense.

This is a story about managing risk. We don't know for certain what will happen under different kinds of outcomes, but the science has given us information about the risks, and we, as people who work on and discuss policy, have to analyze those risks and see which we think is the best way to go. These risks concern, in terms of the actions we can and should take now, in my view, the long term. Most of what is going to happen in the next 30 to 45 years has already been shaped by what we have done in the past and what we are about to do over these next 4 or 5 years. So we have to see this as the long-term issue and risk-management issue, which it clearly is.

Now, if we go on under business as usual, we will move from the concentration of greenhouse gasses in the atmosphere, which we now find around 430 parts per million of CO_2 equivalent to something like 750 parts per million of CO_2 equivalent, possibly a good bit more than that by the end of this century. Now, what would that imply? It would give us a roughly 50/50 chance sometime next century of being 5 degrees or more above preindustrial times, dating roughly from 1850. We are now about 0.8 degrees centigrade. So scientists tell us, and this is the modeling that the best scientists in the world tell us, and it is quite conservative in the sense of the risks that it leaves out, that is a roughly 50/50 change of being more than 5 degrees centigrade above preindustrial times.

If we hold the concentrations, if we stabilize around 500 parts per million, we would hold that probability down to just 3 percent. If we stabilized at 500, we would hold it down to around 7 percent. So whichever of these you choose, you can see that the benefit of action or the cost of inaction is a huge change in the probability of very high temperatures, given the best science that we have available. Now, the consequences of these actions come in water in some shape or form: storms, floods, droughts, sea level rise, as well as, of course, the direct consequences of the heat. I could have told the story in 4 degrees centigrade, 6 degrees centigrade. Five degrees centigrade keeps it simple, and there is a 50/50 chance of getting there sometime next century under business as usual.

Now what does this mean? The last time we were 5 degrees above centigrade about these kind of levels was 30 or 50 millions years ago in the Eocene period. The world was covered in swampy forests, and there were alligators at the North Pole. Now, I am not particularly worried about alligators at the North Pole. That is not the point. The point is that it radically redraws where species, including humans, can live. The last time we were 5 degrees centigrade below where we are now, going back the other way, was very recent, the last ice age, about 10,000 years ago, when the ice sheets came down, roughly, to London and New York? Where were people then? Of course, there were people 10,000 years ago. They were much nearer to the Equator than that.

The clear message is that changes of this kind involve very big movements of the population, and we know that very big movements of population mean not only the hardship around the movements themselves, but also conflict. If the last couple of hundred years has taught us anything, it is that big movements, forced movements of population of that kind lead to conflict. So we can reduce the probabability of being 5 degree centigrade up from preindustrial times, around 1850, by 14 or more percent by strong action, and the cost of inaction is the cost of not doing that. That is one way of looking at it.

The second way of looking at it is to try to apply economic models to these types of risks, to try to quantify the different kinds of risks. I started off as I did because I wanted to illustrate the nature of the risks, the kinds of the risks involved, and that, of course, underlines the difficulty of putting economic numbers to them. But we try as best we can. We try to be analytical about that, and if you do some simple modeling of those risks, in our calculations in the Stern Review, we estimated that averaged over space, averaged over outcomes, averaged over time, the cost would be 5 to 20 percent of GDP. We were cautious about taking these models over literally for the reasons of the description of the risks that I just described. But if you do the best you can, those are the kinds of numbers that you come up with.

Averaging over time does involve discounting. I have dealt with that issue of discounting quite carefully in the Stern Review and at greater length in my Richard Ely lecture to the American Economic Association in January of this year. The concept may worry you, but you have about 5,000 economists getting together to talk to each other, and that is the biggest meeting in the world, and it was the main invited lecture. And those of you who would like to look at the issue of discounting can see my views there. I am more than happy to discuss this issue as we go on later this morning. We did discount in the Stern Review. It is not true to say we did not.

Looking back now, I think we underestimated the risks. Emissions are growing faster than we thought. The carbon cycle is weakening more quickly than we thought. The climate's sensitivity, the amount by which temperature is likely to go up for a given stock of greenhouse gasses looks to be more worrying than we thought, and the speed of change of the planet as a result of global warming, for example thawing of the ice, seems to be happening faster than we thought. So if anything, I think we underestimated the risks, but there is quite a bit of sensitivity analysis given in the Stern Review. You can see how different assumptions affect the results.

So that is the second way of looking at the cost of inaction, 5 to 20 percent of GDP, averaged over space, outcomes, and time, with due caution about what those models can tell you.

Essentially, then, and this is the third way of looking at the cost of inaction, we have to recognize that low carbon growth in the medium term is the only growth story. If we try to continue for a long period with high carbon growth, the disruption that we will cause will undermine growth, so that is a third way of looking at the cost of inaction, that you are trading off low carbon growth with action against, eventually, undermining and stopping growth through the disruption the environment causes by trying to proceed with high carbon growth.

Finally, on seeing this in terms of risks, I think you can look at the commonsensical view of the kinds of errors you can make. If we act as though the science is right, and it turns out to be wrong, we have wasted a bit of money. I will come back to how much in a moment. But we will have more clean technologies. We will have a more biodiverse world. We will have stronger forests and so on. It will be a cleaner, safer place. So if we act as though the science is right and it turns out to be wrong, nevertheless, we are going to have quite strong benefits.

On the other hand, if we act as though the science is wrong, and it turns out to be right, the stock of greenhouse gasses through our failure to control the flows will have built up to a level from which it is very hard to back away. We will have put ourselves, painted ourselves into a corner, or admitted ourselves into a corner from which it is very difficult to extricate ourselves because carbon dioxide lasts such a very long time in the atmosphere.

So a simple, commonsense attitude to risk, I think, points to acting as if the science is right. And of course, you add to that the very high probability that the science is right. You have heard the very powerful statements of the scientists here. I am not a scientist. I am an economist using the science.

Now, I am not sure how long I have left, Mr. Chairman. There is a minute or so more I would like to take with your permission.

Mr. BOUCHER. Another minute or two would be fine, Lord Stern.

Mr. STERN. That is very kind. Thank you very much, Mr. Chairman.

The cost of action: 1 or 2 percent of GDP, around 1 percent if we try to control at 550 parts per million as the eventual stabilization, a bit more, say 2 percent, if we try to control at 500. Others have confirmed these estimates since the Stern Review was published, International Energy Agency, McKinsey, the Potsdam Institute on Climate Change. Quite a few studies have pointed quite strongly in that direction.

But I do want to emphasize that these cost estimates require good policy. This is a market failure. We have to fix the market failure. We have to rely on the markets. This isn't just about control. It is about making markets that are failing, work better. That is why people discuss a carbon tax. It is fixing a market failure. That is why people discuss cap-and-trade. It is fixing a market failure, and relying on the markets to give us efficient outcomes.

Good policy means making it clear to people where we are going so those in the private sector who have to make the long-term investments have the time to adjust, have the time to reject their replacements to adopt the new technology. There will be many gains to offset against this cost. I have already mentioned, biodiversity, energy security, and so on. We will have new markets for these new technologies which could well trigger an exciting new set of opportunities for investment. We do have to encourage technologies. We do have to invest strongly, public and private money in technological development, but we can do a great deal with the technologies which we recognize now or can develop quite quickly.

Competitiveness is, of course, an issue, but 1 or 2 percent on your cost doesn't destroy your competeveness when you have got relative wage rates of 5, 10, 15 times that of some of the competititors. It is good productivity that overcomes those kinds of costs. It is like a one-off, 1 or 2 percent increase in prices. Some industries, it is more difficult, and direct action there will of course be important.

Now, finally on the global deal, and I can only say a word or two here and leave the rest of this for questions, but let me emphasize very strongly that acting on development, acting on world poverty, and acting on climate change come together. If we don't act on climate change, we will derail development. If we try to act on climate change in a way that undermines development, we will never get a global deal. We will never work together. So the world is now looking to the United States of America. I do believe that the big countries of the developing world could make a big response if the

United States takes the lead now. I am more than happy to ask questions and answer questions as to just how that might happen.

Thank you very much for your indulgence, Mr. Chairman.

[The prepared statement of Mr. Stern follows:]

TESTIMONY OF LORD NICHOLAS STERN

BEFORE THE

COMMITTEE ON ENERGY & COMMERCE
SUBCOMMITTEE ON ENERGY & AIR QUALITY

U.S. HOUSE OF REPRESENTATIVES

JUNE 26, 2008

Climate change: Costs of inaction, Targets for action

Chairman Boucher, Ranking Member Upton, distinguished members; I appreciate the opportunity to testify before the Energy & Air Quality Subcommittee of the House Committee on Energy & Commerce on the critical matter of the costs of doing nothing to stop climate change.

I am Nicholas Stern, IG Patel Professor of Economics and Government at the London School of Economics and Political Science. I was an adviser to the UK Government on the Economics of Climate Change and Development, reporting to the Prime Minister and the Chancellor of the Exchequer as Head of the *Stern Review on the Economics of Climate Change*. I was also previously Head of the Government Economic Service; Second Permanent Secretary to Her Majesty's Treasury; and also Director of Policy and Research for the Prime Minister's Commission for Africa.

Before entering Government Service I was World Bank Chief Economist and Senior Vice President, Development Economics. Before this, I was Chief Economist and Special Counsellor to the President European Bank for Reconstruction and Development.

My research and publications, of which there are more than 15 books and 100 articles, have focused on the economics of climate change, economic development and growth, economic theory, tax reform, public policy and the role of the state and economies in transition. The *Stern Review on the Economics of Climate Change* was published in October 2006.

Mr. Chairman, I request my statement on *Climate change: costs of inaction, targets for action* be entered into the record.

1. Risk

Greenhouse gas emissions (GHGs) represent the biggest market failure the world has seen. GHGs damage others and without policies we do not pay for that damage. We all produce them, people around the world are already suffering from past emissions, and current emissions have the potential to cause catastrophic damages in the future. These features, particularly the global nature of the link between emissions and damages, call for a global response. Failure to analyse the problem in terms of the great risks, the long term and global cooperation will, and has, produced approaches to policy which are misleading and dangerous. The arguments for strong and timely action are overwhelming. The costs of inaction, that is continuing with current paths and practices, or business-as-usual (BAU) should be measured in terms of the possible outcomes and damages relative to a path for the world that sets sensible targets.

The relationship between the stock of GHGs in the atmosphere and the resulting temperature increase is at the heart of any risk analysis: it is the clearest way to begin and anchors most of the discussion. There are many models that estimate these links: running a model many times for different parameter choices, yields probability distributions of outcomes – in other words allows us to take into account the uncertainty in the link between emissions and temperature changes.

Table 1: probabilities of exceeding a temperature increase at equilibrium (%)

Stabilisation Level (in ppm CO_2e)	3.6 F (2°C)	5.4 F (3°C)	7.2 F (4°C)	9 F (5°C)	10.8 F (6°C)	12.6 F (7°C)
450	78	18	3	1	0	0
500	96	44	11	3	1	0
550	99	69	24	7	2	1
650	100	94	58	24	9	4
750	100	99	82	47	22	9

Source: based on Stern Review box 8.1 (Stern, 2007, p. 220)

Current concentrations of GHGs are around 430ppm CO2 equivalent (CO2e – which aggregates carbon dioxide with other GHGs), and we are adding about 2.5ppm CO2e per year. This rate appears to be accelerating, particularly as a result of rapid growth of emissions in the developing world. There seems little doubt that, under BAU in the absence of any restraining policy, the annual increase in the overall quantity of GHGs would average somewhere above 3ppm CO2e, potentially 4ppm CO2e or more, over the next 100 years. That is likely to take us beyond 750ppm CO2e by the end of this century.

This level of concentration would give us, if we were to stabilize there by 2100, a 50-50 chance of a temperature increase over 9F (5°C). We do not really know what the world would look like at 9F (5°C) above pre-industrial times. The most recent warm period was around 3 million years ago when the world experienced temperatures 3.6F (2°C) or 5.4F (3°C) higher than today (Jansen et al., 2007, p.440). Humans (dating from around 100,000 years or so) have not experienced anything that high. Around 10-12,000 years ago, temperatures were around 9F (5°C) less than now and ice sheets came down to latitudes just north of London and just south of New York. As the ice melted and sea levels rose, and taking into account the changed topography, Britain separated from the continent and there was major re-routing of much of the global river flow. These magnitudes of temperature changes transform the planet.

At an increase of 9F (5°C) most of the world's ice and snow would disappear, most likely including the Arctic and Antarctic ice sheets and the snows and glaciers of the Himalayas. The former effect would, taking the two ice sheets together, eventually lead to sea-level rises of over 10 metres, possibly much higher. The latter would thoroughly disrupt the flows of the major rivers from the Himalayas, which serve countries comprising around half of the world's population. There would be severe torrents in the rainy season and dry rivers in the dry season. The world would probably lose more than half its species. The intensity of storms, floods and droughts is likely to be much higher than present. Further tipping points could be passed, which together with accentuated positive feedbacks could lead to further temperature increase. The last time the temperature was in the region of 9F (5°C) above pre-industrial times was in the Eocene period around 35-55 million years ago. Much of the world was covered by swampy forests and there were alligators near the North Pole. The point is not particularly about alligators, it is about transformation of the world: these kinds of changes would bring very radical changes to where and how different types of species, including humans, could live. Many of the changes would take place over 100 or 200 years rather than thousands or millions of years.

Whilst we cannot be precise about the magnitude of the effects associated with temperature increases of such size, it does seem reasonable to suppose that they would be, or at least likely to be, disastrous. They would probably involve very large movements of population from regions where human life would become extremely difficult or impossible. History tells us that large movements of population are likely to bring major conflict and this potential movement would probably be on a huge scale.

The cost of inaction is the high probability of these devastating impacts and conflicts. As Table 1 shows, we can cut the probability of being above 9F (5°C) from 50% to 3% by stabilizing at 500ppm CO2e. We cannot be very precise about these probabilities and the ones we have used here, from the Hadley Centre, are probably cautious. The point, however, is that the reduction in risk is huge. There are corresponding reductions for 7.2F (4°C) and 10.8F (6°C) and other temperatures (see table). We focus on 9F (5°C) to make the point as simply as possible.

By using extremely simple models one can try to quantify the avoided dangers although our description of the avoided risks should make it clear that it is very hard to attach convincing numbers to the potential losses. Even from a very narrow perspective, world wars seem to involve losses of 15% or more of GDP and the conflicts we are discussing are likely to be on a bigger scale, longer lasting and, of course, affect much more than GDP. The Stern Review, which looks at damages up to 2200 and extrapolated thereafter, concluded that such costs can be estimated as being equivalent to a 5-20% loss in the range of the world GDP averaged over space, time and possible outcomes. Such models can provide useful insights but we warned strongly against taking them too literally

A recent report by Frank Ackerman and Elizabeth Stanton at Tufts looks specifically at the effect of uncurbed emissions in the US. By 2100 the increase in temperatures would be between 5.4-9F (3-5°C) – this would make temperatures in Anchorage, AK similar to today's temperature New York City, but that is not really the main point. The effects of climate transformation are largely through water in some shape or form. The effects of hurricanes, destruction of residential real estate, changes in the energy and water infrastructure would, according to the authors, cost the US around $2 trillion. The overall cost of BAU at 2100 would be greater, particularly taking into account the impact of the effects of changes in the rest of the world to the US. The overall cost, using a methodology similar to the one adopted in the Stern Review, would be equivalent to a 3.6% loss of the US GDP in 2100. We should emphasise, however, that there are many likely, larger, and deeply damaging, effects which will occur after 2100 and these calculations take no account of the effects on the USA of the damages and devastation which occur outside the USA.

2. Recent developments on risk and damages of climate change

There are a number of factors which climate change scientists and economists have raised recently which point to a worsening of the prospects on climate risk.

First, recent data – particularly from developing countries – indicates that emissions are growing more quickly than we thought. For example, a recent study by Max Auffhammer, UC Berkeley, and Richard Carson, UC San Diego, indicates that carbon emissions in China, over the 2004-2010 periods, are growing at 11% p.a... BAU assumptions used by the IPCC projected a growth of only 2.5-5% p.a. At this pace by

2010 China would have increased its carbon emissions from 2000 by around 600 million metric tons. To put in another way, the projected annual increase in China alone over the next several years is greater than the current emissions produced by Germany. If indeed emissions are growing more quickly than we thought, then the dangerous CO_2e concentration levels, associated with higher probabilities of disastrous temperature increases, will be reached much more quickly.

Second, the key feedbacks of the carbon cycle, such as the reduction in the absorptive capacity of the oceans, and thus the reduced effectiveness of a key carbon sink, and the release of methane from the permafrost, have not been taken into consideration in the projected concentrations increases quoted here. It is likely that, if these factors were accounted for, stabilizing at stocks associated with lower probabilities of disastrous temperature increases could be even harder.

Third, it is increasingly clear that we know little about what would happen in the world if we were to see very high concentrations of GHGs: indeed given the nature of feedback mechanisms, scientists agree that damages associated with very high GHG concentrations could be enormous. Most of the current research on damages makes conservative assumptions about such 'extreme events'. As the Harvard economist Martin Weitzman, among others, has convincingly shown in his research, taking such extreme events into consideration escalates the impact of climate change – and its potential cost to the economy.

In light of such evidence, it is likely that the balance of the evidence implies that the risk in the IPCC 4th Assessment Report and the Stern Review may be underestimated.

Therefore the opinion, which some commentators expressed, that the Stern Review was alarmist, is simply wrong.

3. Discount rates and damages

Let me, lastly, touch upon an important and much misunderstood issue: discounting. This debate is inevitable in the context of climate change, as it relates to how to evaluate damages that will burden future generations. The basic question here is how economic analysis should account for the fact that actions taken today will affect later generations. If we do nothing now, we will be shifting significant costs to the future. Economists use discounting to evaluate future costs and benefits, making it an essential tool to carry out such analysis. The popular press, and more than one professional economist, have misunderstood this issue. Earlier this year I was invited to give a lecture in honour of Richard Ely, the founder of the American Economic Association (AEA), during the Area's Annual Meeting. It is the principal invited lecture of the main gathering of professional economists in the world. This lecture, which has now been published in the American Economic Review, carefully sets out the theoretical basis for the approach to inter-temporal judgements and discounting, including that used in the Stern Review. To summarise, in this paper I show how in the Review we discount impacts for the right reasons – that we are (we hope – although climate change could destroy this) likely to be substantially wealthier in the future, so the value of an extra dollar then is likely to be lower than the value of an extra dollar now.

What the Review does not do is go further and discount future generations additionally, purely on the basis of birthdates; this is called pure time discounting. Discounting the future simply because it is the future is to adopt the value judgment that we should *a priori* care less about future lives. Many would find this unacceptable: for example, to have a pure time discount rate of 2% means attaching half of the weight to someone born in 2005 relative to someone born in 1970, assuming they have the same lifetime pattern of consumption. Those who advocate for such an extreme approach should provide a convincing argument. They do not. Many philosophers, and indeed many economists (including Ramsey (1928, p.543), Pigou (1932, pp.24-5), Harrod (1948, pp.37-40), Solow (1974, p.9), Mirrlees (Mirrlees and Stern, 1972) and Sen (Anand and Sen, 2000)), believe this to be arbitrary, and providing no serious ethical basis for long-term public policy choices. Reasonable people may differ on ethical positions but this type of heavy discounting of lives requires justification. The approach of treating people with different birthdays in an equal way is a direct invocation of a notion of equality that is standard in most treatments of justice and rights.

Furthermore, it is not possible to read off inter-temporal ethics for this type of decision from the behaviour of markets. We cannot see a collective expression in the markets of what, acting together, we should do for ourselves and our descendants over the 100 or 150 years. Current market interest rates tell us only about individuals' willingness to invest, lend or borrow today for benefits in the relatively near term. How society should treat young or unborn generations is a different question. Neither can we say that we should invest in something else and pay to deal with the damage from climate change later. This makes the mistake of ignoring relative price changes:

the rate of accumulation of GHG emissions and the potential irreversibility of environmental damages imply that the price of later action (when GHG concentrations will be higher and the environment damaged) will be much higher. In summary my own view is that much, although not all, of the discussion on discounting has been in ignorance or in dismissal of the right tools of analysis for a problem which involves non-marginal changes, major risk and imperfect markets. There is no substitute for an analysis which takes these issues seriously and for engaging in direct ethical discussion.

The latest evidence on the science which I mentioned earlier, however, has an interesting implication: even if we were to use much higher discounting the higher risk of severe damages would imply that the overall numbers on cost do not change significantly from the original results of the Stern Review.

4. Conclusions

To conclude, it is dangerous, in my view, to advocate weak policy and procrastination and delay under the banner 'more research to do' or 'let's wait and see'. The former argument is always true but we have the urgent challenge of giving good advice now, based on what we currently understand. The latter is misguided – waiting will take us into territory which we can now see is probably very dangerous and from which it will be very difficult to reverse. The same is true of policies which speak of a 'slow ramp'. If we conclude that, whatever the merits of the argument, it is too difficult and costly to implement the policy of strong and timely action, then we should at least be clear about taking the responsibility for the great risks of moving to the very high

GHG concentrations and resultant damages which are likely consequences of no, weak, or delayed action.

The common sense analysis of risk is clear. If we assume the science is right, and act correspondingly, and it turns out to be wrong, we will have some new technologies and a cleaner and safer world. If we assume the science is wrong and delay action and it turns out to be right, then we will be unable, except at a very high cost, to back out.

Our analysis of climate change risk, and the associated economic risk of damages, points to identifying a target which reduces the risk of exceeding dangerous temperature changes: taking on a stock target of around 500ppm CO2e would reduce the probability of exceeding temperatures higher than 5.4F (3°C) to about 50-50, the absolute minimum we should aim for. Many would argue that a 50-50 risk of a 5.4F (3°C) increase is too dangerous. This target, and the corresponding path of emissions, is compatible with roughly halving all GHG emissions by 2050, with respect to 1990. We estimate that the cost of action of stabilising at around 500ppm CO2e is manageable, in the range of 1-2% of global GDP in 2050. Similar results have emerged from recent research by the IPCC (Edenhofer et al. 2006), McKinsey and Company (2007), and the International Energy Agency among others.

This is the kind of judgement that people take when considering various forms of insurance, or design of buildings or infrastructure, or new medical treatments. They try to be as clear as possible on consequences and costs, bearing in mind that both are uncertain and that risk is of the essence, whilst also being aware that it will often be difficult to put a price or money values on consequences and risks.

The target to halve emissions by 2050, which is also what world leaders have agreed at the G8 meeting at Heiligendamm in June 2007, is compatible with such a judgement call. If we decide to halve our GHG emissions by 2050 from the 1990 benchmark, then the world must to go from around 40GT CO2e in 2000 (which was only a little about 1998) to roughly 20GT CO2e in 2050. World population, by 2050, is projected to be around nine billion, which brings us to a world average target of around 2T per capita.

For all countries to reach such per capita levels requires early and concerted action. Most developed countries (including Japan and most of Europe) emit around 10-12T CO2e per capita, with a cluster (including the USA) in the range 20-25T. These economies would therefore need to cut per capita emissions by at least 80% by 2050; for the latter cluster the reductions would have to be 90%. By contrast, developing world per capita reductions are generally lower. The average per capita emissions in China is currently around 5T, and in India approaching 2T, and these are set to grow rapidly. By 2050, out of a total global population of nine billion, some eight billion will reside in what is currently the developing world. These numbers make clear that a reduction in global emissions of 50% relative to 1990 levels by 2050 simply cannot be achieved without per-capita emissions in developing countries averaging around 2T.

A target of 2T per capita emissions by mid-century is so low that there is little scope for any major group to depart significantly above or below it. If one or two large countries, developed or undeveloped, were to manage only to reduce emissions to, say, 3T or 4T per capita, then it would be difficult to see which other major grouping of countries would be able to get emissions close to zero: and the global target would be unlikely to be reached. Thus, as a matter of pure arithmetic, all countries must play their part in aiming for around 2T per-capita emissions by the middle of the century and all emissions trajectories should be designed with this target in mind.

All major groups getting to 2T per capita is a pragmatic approach to cutting emissions by 50% by 2050 and not a strongly equitable one. It takes little account of the greater per capita contributions of the developed countries to the historical and future contributions to the stock of GHG emissions. This is particularly true for fast growing economies, such as China: per capita emissions in China are currently at 5T per capita, well above 2T per capita and are projected to increase very quickly over the next decade. A target of 2T per capita by 2050 would, therefore, put substantial pressure on these countries to contain and reduce their emissions during a period of rapid growth. Modelling the cost of mitigation, based on the pan-European Poles model, indicate that the cost to China of such a target would for the year 2030 be approximately 3% of GDP. If the 'industrialisation party' started in 1850 then we are asking everyone to drink out of the same size glass 200 years later notwithstanding all the drinking out of our shared well – the atmosphere – which took place before. That is a weak notion of equity.

Given the substantial effort that developing countries will need to make to reach the 2T per capita, the 80% reduction in GHG emissions necessary in developed countries is, therefore, not only a matter of arithmetic. It is a necessary step for the developing countries to take part in this global effort. They cannot halt their drive for development, but we know that high carbon growth across the world will make climate stability and climate security unachievable. The answer must be low carbon growth, not low growth. High carbon growth will eventually undermine growth itself – it is not a medium- or long-term growth option.

To achieve low-carbon growth, developing countries look to the rich world as originators of the bulk of the stock of GHGs and as holding the resources and the technologies. To be in a position to take on their own targets, they will need to see progress on the following four elements:

(i) Developed countries taking on ambitious targets immediately;

(ii) Demonstration that low-carbon economic growth is possible;

(iii) Substantial financial flows to countries with cheap opportunities to abate GHGs; and

(iv) Low-carbon technologies available and shared, allowing developing countries to innovate, develop, and ultimately export their own low-GHG technologies.

Thus, conditional on progress on these elements, it is reasonable to ask them to commit now to commit explicitly by 2020 to targets consistent with 2T per capita in 2050 and to put together credible plans between now and then to get onto such a path. And let us be clear that their transition will not be easy: they require strong collaboration and support in making this change as they seek to overcome poverty.

There is a key point here about carbon trading: the desired outcome is not achievable without a global market able to mobilize the scale of financial flows necessary to implement the low-carbon technologies where they can be developed and deployed most cheaply. The details of such markets are of great importance, and will be an important part of the global deal ahead.

The challenge is far-reaching, comprehensive and global, but it is manageable. The technological transformations and flows of funds required across countries and sectors will be large, the institutional and implementation challenges significant, but the costs of action are affordable and entirely consistent with sustainable growth and development. By contrast, the alternative of inaction or delay is not. Low-carbon growth is the only growth option. High-carbon growth will eventually undermine the prospects for all. The world is looking at the US to take the lead, the future of the global deal is in your hands.

Lord Nicholas Stern – Outline of Testimony – June 26, 2008, 10am

The *Stern Review on the Economics of Climate Chance* was published in October 2006. This independent Review was commissioned by the Chancellor of the Exchequer, reporting to both the UK Chancellor and to the Prime Minister, as a contribution to assessing the evidence and building understanding of the economics of climate change. It was possibly the most comprehensive review ever carried out on the economics of climate change.

The *Review* first examines the evidence on the economic impacts of climate change itself, and explores the economics of stabilising greenhouse gases in the atmosphere. The second half of the Review considers the complex policy challenges involved in managing the transition to a low-carbon economy and in ensuring that societies can adapt to the consequences of climate change that can no longer be avoided.

The *Review* goes on to consider more recent scientific evidence, the economic effects on human life and the environment, and approaches to modelling that ensure the impacts that affect poor people are weighted appropriately. Taking these together, the *Review* estimates that the dangers could be equivalent to 20% of GDP or more.

In contrast, it finds that the costs of action to reduce greenhouse gas emissions to avoid the worst impacts of climate change can be limited to around 1% of global GDP each year. People would pay a little more for carbon-intensive goods, but our economies could continue to grow strongly. The *Review* also looks at the potential opportunities from a shift to a low-carbon economy: it finds that markets for low-carbon technologies will be worth at least $500bn, and perhaps much more, by 2050 if the world acts on the scale required. Tackling climate change is the pro-growth strategy; ignoring it will ultimately undermine economic growth.

In the document *Key Elements of a Global Deal on Climate Change,* published in April 2008, Lord Stern and a group of international experts build on the results of the Review to propose a set of principles around a global deal on climate change. Effectiveness (reducing dangerous emissions to the required level), efficiency (doing it at least cost to the economy), and equity (taking into consideration historical responsibilities and development imperatives) are the three fundamental principles that the document suggests should be at the core of any deal on climate change.

Lord Nicholas Stern – Outline of Testimony – June 26, 2008, 10am

Climate change: costs of inaction, targets for action.

Lord Stern – Outline of Testimony to Committee on Energy and Commerce, US House of Representatives.

1. Risk:

- Outline of risks of climate change
- Probabilities of exceeding a temperature increase at equilibrium
- where would inaction take us: 5C increase is world changing
- Stock and flow targets, and the cost of achieving them
- The core results of the Stern Review and US specific results

2. Recent developments on risk and damages of climate change

- Recent evidence on risk of climate change
    1. Emissions are higher than expected
    2. Carbon sinks are weakening
    3. Taking into account extreme events when assessing damages.
- Consensus is creating around danger of underestimation of damages

3. Discount rates and damages

- Need for an ethical discussion around discounting
- Pure time preference and generational discrimination.
- Why you cannot import a discounting structure from the markets.

4. Conclusions

- The global target: 50% GHG reduction by 2050: 2T per person by 2050
- What does it mean for developed and developing countries
- The deal needs to be global: how to ensure developing countries participate
- Leadership role of the USA

Mr. BOUCHER. Lord Stern, thank you very much for that very thoughtful testimony and for expanding this subcommittee's understanding of the costs of climate change, both the cost of acting and also, important to your points, the costs of not acting. You note in your report that fossil fuels, by the year 2050, will continue to comprise a very large portion of the world's energy supply. In fact, I think you estimate that fossil fuels, collectively, will remain at more than 50 percent of global energy supply. And in view of those realities, how important do you believe it is that carbon-capture and -sequestration technologies be developed as part of an overall strategy to control greenhouse gases?

Mr. STERN. Basically, economists do believe in the market mechanism. I think it is important to get the incentives right and let the market come up with the best technologies. But I do think that carbon capture and storage for coal, in particular, is of enormous importance.

Coal is responsible, around the world, for 40 or 50 percent of electricity generation. India and China, countries growing very rapidly, will be using about 80 percent coal for the next two or three decades, probably longer, for the good reason that they have it themselves. They are not dependent on outsiders. And at the moment, it is quite low cost, and of course, important to them, they can use it very quickly, and speed is of the essence. So we know that coal is going to be used. Some people might wish that it wasn't, but it will be. So it seems to me that wise policy is to act on what you see to be the reality, not to wish the reality as something different.

Within 7 or 8 years, if we as a world develop, say, 30 carbon capture and storage plants for coal, you need a spread of these things, because there are different kinds of coal. There are different kinds of geology and so on. But we could, as a world, get those examples up and running quite quickly, within 10 years, and that would give us the examples that we need to test out whether this very promising technology is really going to work on scale. If it doesn't work on scale, then the problem is going to be much more difficult. But I think the indications are that it really could work on scale.

Mr. BOUCHER. Thank you very much.

You mentioned in your testimony the importance of international collective action to address the global problem of greenhouse gas emissions, and I know that in the course of your work, you have had extensive conversations in developing countries and China, and perhaps most of the point of this question in India. I understand that you have had extensive conversations with the Prime Minister of India concerning these matters.

My question to you is how important is action by the United States to establish a mandatory problem to control greenhouse gasses, as a motivator for corresponding action by the major developing countries, China and India. What kind of response do you think we could expect from those countries, once the United States by its own example has controlled greenhouse gas emissions through a mandatory program here?

Mr. STERN. I am much more optimistic, Mr. Chairman, on a strong response than I would have been 2 years ago. I have been working in India for 35 years and living there for quite extended periods. Both on policy and in rural areas, I have been working and living in China for nearly 20 years on and off. Two years ago those countries would have said you rich countries caused this problem with your high-carbon growth in the past. Seventy percent of the greenhouse gasses are down to you. You sort it out.

They, now, I think see this in a very different way. That resentment is still there. It is a political reality that we all have to recognize, but they say it in a different way. In 2050, 8 billion out of the 9 billion people that there will be in the world, will be in the currently developing countries. We hope many of them, of course, are better off by then, but they will be in the currently developing countries. They realize that you can't get action for a world of 9 billion just through the action of the 1 billion in the rich world. It just obviously doesn't stack up. So they realize that the world is shaped by their actions looking forward.

They recognize very clearly just how vulnerable they are. The major rivers of Asia, just to give one very important example, rise in a few hundred square kilometers of the Himalayas. The glaciers in the Himalayas have retreated about 15 percent in the last 40 years. No surprise, the floods in Bahia in India last year were record floods on a scale never seen before. The Chinese people and authorities are very much concerned about the way in which the water behaves in their great rivers, for example, the Yellow River and the Yangtze. Much of China is struggling with problems with transferring water from South to North, and for them the disruption of the flow of the Himalayas is the big issue. Many cities, of course, in India and China are on the sea and vulnerable to sea-level rise and to the increased intensity of typhoons. This is a very clear indication to them that they are vulnerable.

So they recognize, first, that they are 8 billion out of the 9 billion of people in the developing world, second that they are vulnerable, and third that they are potential deal-breakers, which they are. So if you put those three things together, it really focuses the mind.

And China is already taking quite strong action. It is reforesting. It is not deforesting. You can't sell an American car in China. It doesn't satisfy the emissions requirements. China has an export tax on energy-intensive industry, equivalent to roughly $50 a ton of CO_2 equivalent, since the end of 2006. It has a 5-year plan of 20 percent reduction targets for energy-to-output rations. But it is still opening one or two major coal-fire stations every week.

But I think we have to see, as it were, a growing understanding of this problem and the challenge. India is about to publish its climate change action plan. It should be out in the next week or so. And I have talked at some length with the Prime Minister and the head of the planning commission, the Finance Minister, and the Minister of Science and Technology in India on those issues. I spent an extended period there in March and April.

They are very much concerned with those issues. I think it is fair to say that India is a bit behind China in understanding and action, in a very broad sense, on these issues, but changing very fast in both countries. But that resentment that I described at the beginning is still there and it won't go away. So I think we have to see this as a whole package, respect the people that we are talking to as a rich world, just as when I am in China, I try to explain the great strides United States is making in technology, for example.

So my own assessment is that the probability of response is much higher than it was a couple of years ago. If we all approach this in a collaborative way, then I think the response could be very large. But it is absolutely clear that the world is looking to the United States for leadership on this issue.

Mr. BOUCHER. Thank you very much, Lord Stern. The gentleman from Michigan, Mr. Upton, is recognized for 5 minutes.

Mr. UPTON. Well, thank you, Mr. Chairman, and I appreciated your testimony, Lord Stern, and I too am one who wants to see us reduce greenhouse gas emission, and I think as a Nation we have made some pretty good strides proving that it is not business as usual over the last couple of years.

I would note that Ms. Harman and I passed successful legislation, enacted last year, that is going to change light bulb standards for the entire United States. We are going to phase out the 100-watt incandescent bulbs. And let us say for the record that those bulbs are already being built and are already in our stores and are without mercury or lead, a great stride by a number of manufacturers, and they happen to be making them in America, which I think is a really good thing.

I am from Michigan, which you may know is called the Auto State. Mr. Stupak and Mr. Dingell are members of committee, and myself, are all from Michigan and made a pretty tough vote last year to increase mileage standards for automobiles, and we saw that happen for the first time since the '70s.

There are a number of us on this subcommittee, certainly including chairmen Boucher and Dingell and others, Barton, on promoting nuclear energy. As you know, our about 20 percent of our Nation's power is generated from nuclear. We know to address our energy needs by the year 2030 we are going to need to put online more than 50 new reactors to just maintain that 20 percent. We want to see that happen. We also know that we have to address the issue of waste, and I think you are going to be seeing, I hope, some bipartisan legislation moving in both the House and Senate, long term, that can deal with that.

We have seen changes in appliance standards, not only in electricity, but also on water, housing standards. We need to renew the R&D tax incentives for wind and solar, and I actually believe that we come to an agreement on a renewable portfolio standard that makes sense in this Nation, which we were not able to do this last year.

I have a plant, a company in my district called Eaton that is developing a new hybrid engine for diesel vehicles. And as an example, this last year I saw, whether it be a Fed-Ex or a UPS truck, they believe it can save literally a thousand gallons of diesel a year on the mileage they usually drive. So we are making some good steps.

You talked a little bit about carbon capture and sequestration. Mr. Boucher, myself, Mr. Barton, Mr. Shimkus, Mr. Whitfield here, and others, are promoting a bill that will literally generate a billion dollars into a fund to make sure that we can see that technology come about and help the coal industry across the country move forward.

Earlier this week I sat down with Lord Turner who I think you know is developing a plan by December 1 to show where the U.K. is to hit the various targets by 2020, 2025, 2050. I know our subcommittee is anxious to see that report, see how the U.K. intends to meet the targets that it establishes and what that political reality will be.

I will ask you a question, as you spent extensive time in both India and China. The hearings that we held last year I don't think telegraphed very well what those two countries intend to do. To summarize, I would say that the gentleman from India said that it would in essence be political suicide for them to put on any new controls in the generation of electricity. Coal, as you noted, they are putting a new coal plant online literally every week in China. Where are we in terms of what you think the political reality is of both those two countries as it relates to climate change?

Is that clock moving too fast?

Mr. BOUCHER. You are doing that.

Mr. UPTON. Let me stop and let you respond to that, and then, I guess I am going to be out of time.

Mr. STERN. Thank you very much.

The potential in the United States for technological progress all of us non-Americans have great respect for. We will still have cars as we go to 2050 and we try to cut back on carbon emissions. We will still have electricity, but we have electricity which is generated in a close to zero-carbon way, and we will have cars, which in large measures, are run in other ways than fossil fuels, whether it be electricity from zero-carbon electric sources, whether that is stored as hydrogen in some shape or form. And I am confident that those kinds of technological advances can be made quite quickly.

France went from very small to around 75 percent nuclear in about 20 years after the oil-price shocks. The Brazilians, whatever you think about ethanol from sugar, the Brazilians went very quickly to all of their cars being flexible as to which kind of fuel that they can use, and if you go to a Brazilian gas station, it is like going to a bar. You choose whatever pump you want, and you have got a big choice of what you drink or what you put in your tank. So they developed the cars, the infrastructure, the techniques, very quickly.

Big parts of Germany, in a period of 5 years, have gone to 50-percent wind, and I understand that wind in this country is very, very prominent in new investment in electricity generation.

Some of these things with the right kind of support for technical progress with the clear signals from government about where the economy is going can get very rapid responses. So it sounds sort of dramatic to talk about close-to-zero carbon electricity, close-to-zero carbon transport by 2050, but that is 40 years away, and we can also already see, as you have described, the kind of technologies that might be used. I think we have to have a very open mind about those technologies. It would not make sense to rule out nuclear, carbon capture, and storage for coal, ethanol, or whatever. We have to find the best ways, and we have to do it in a way that fits with the market and is also socially responsible.

On India and China, the public face is often the negotiating face, and the political realities that our friends from India and China pointed to are political realities. That is why it has to be a collaborative response. My friends in senior decisionmaking bodies in the planning commissions now say to me, look, Nick, you have got my cell phone number. Just as soon as that carbon capture and storage plan is working in the U.K., give me a call and we will go and visit it together, and then we will talk about whether we, in India, should be using carbon capture and storage, how you are going to help us with the technologies, whether you are going to allow carbon markets that allow us to sell you the carbon reductions.

That is why I think it is so important, the advance of technology in the rich world, and the political realities throughout the world, that we push ahead with these technologies as rapidly as possible. The only one I underlined was carbon capture and storage for coal for the reasons I described before. I think we have to push ahead with all of them. But if we do that, if we show strong targets ourselves, we show low carbon growth, we show the sharing of technology, and we involve the whole world in the carbon markets so the reductions can be done where it is as cheap as possible, then, I think that we will get a big response. And if we commit ourselves to that path, I think we will get a big response.

Mr. BOUCHER. Thank you very much, Mr. Upton and Lord Stern. The gentlelady from California, Ms. Matsui, is recognized for 5 minutes.

Ms. MATSUI. Thank you, Mr. Chairman. Lord Stern, you describe greenhouse gas emissions as the biggest market failure the world has seen, and I ask you as an economist, if we address this failure by applying a price to carbon, how can we best make sure the price is felt by those most able to adopt the necessary corrections, while not punishing those unable to afford it?

Mr. STERN. It is clear that if you ration by price, then the people who are poorer find it more difficult than the people who are richer. That is true, whether we think of apples or cars or greenhouse gas emissions. So what do we conclude from that? We conclude that governments have to think about efficient markets to fix this very big market failure, and they have to think about the distribution policies, the tax and transfer systems, for example. So I think the right way to attack poverty and changes in the poverty is through the tax and transfer systems, not by distorting the markets. So I think we have to do both. Fix the market failure, and think about the distributional aspects of all government policies, not just this one.

And we also have to get, I think, a fix on the size of the problem. Forty dollars per ton of CO_2 is the kind of ballpark that would promote many of these technologies. It is equivalent to about 40 cents on a gallon of gasoline. Now, that is significant. It is not small. But neither is it big, relative to the kind of increase in the price of gasoline we have seen.

So I think we must in our polices recognize the distributional implications. The right way to do that is not to abandon pricing. It is to think through, as we do every day in making public policy, about our tax and transfer systems.

Ms. MATSUI. You touched on developed countries, and you described some of the ways of how countries might take leadership on the issue of climate change. As you see from your interactions around the world, and you addressed it to a certain degree about how, for instance, India and China have basically said they are looking to us, but also being very resentful of what we are not doing, in essence. Do you see a situation where the developing countries and the United States might have a situation where we are able, in essence, to look broadly? We are looking at market things in this country, but across the world, in essence, because we are counting many problems in as far as balancing this out, that we could take one country or two countries and establish some sort of relationship where we can actually come to some sense of what we are doing and what they are doing and try to address some of the basic concerns we might have. I realize that is very broadly speaking, but it seems to me that we are always looking at China and India. Maybe we should look at India to see what their concerns are and what our concerns are and move forward on maybe one aspect of that. I always like to see where we can find some commonalities, where we can find some things that we agree on, and have the other things that we disagree on put to the side of it.

Can you see in your travels and your interactions what we might be doing with, for instance, India?

Mr. STERN. I think the collaborative spirit that you describe is of enormous importance, and it would get a good response. Just to give you one example of the way in which Indian thinking has developed, the Prime Minister, last year, around the G-8 Summit which took place in Germany in June, indicated that India, in terms of emissions per capita, would never be above the OECD average. So that was actually saying, well, let us put history to one side. Let bygones be bygones. Our emissions per capita will never be above yours.

Now, India is currently around two tons per capita. Europe, just to take that example, is 10 to 12 tons per capita. Europe will probably be down to seven or eight sometime before 2030, and India could be close to that without much strong action by them.

So it is an indication that that offer that was made is one that actually becomes directly relevant quite soon, because you can't turn down in a moment. You have to plan ahead to turn down. So I felt that that was one example of openness on quite a major scale from India, which is essentially saying bygones are bygones. We do feel strongly about them, but let us look forward. Let us act together.

Technology, I think, is an absolute key area of collaboration. I think collaboration with both India and China on carbon capture and storage for coal would be one example that is extremely important. But they will be looking to the rich nations to do some proving first, as well as trying things out in those countries. But we have to set that in the context of a global deal. This kind of collaborative behavior in the specifics is terribly important, but we have to keep our eye on the global deal, and we have not got much time, because that needs to be settled in Copenhagen at the end of next year.

Ms. MATSUI. OK, thank you, Lord Stern.

Mr. BOUCHER. Thank you, Ms. Matsui. The gentleman from Texas, Mr. Barton, is recognized for 5 minutes.

Mr. BARTON. Thank you, Mr. Chairman. This is our week for British Lords. We had Lord Reed on the oil speculation hearing on Monday in the Oversight Subcommittee, so we have had two Lords in one week. I guess that is a good thing. Anyway, we are glad to have you.

Lord Stern, you said in your introduction that you are here as an academic, and I accept that your academic credentials are impeccable. I do think, though, that it is fair to point out that in your nonacademic endeavors you have economic interests that benefit if we adopt some of these carbon-reduction methodologies in the United States and worldwide. Is that true or not true?

Mr. STERN. I work one day a week as a special advisor to the chairman of HSBC on climate change and development issues, and I work half a day a week as vice chairman of the IDEA group, which is looking at carbon market ratings, so that is the involvement.

Mr. BARTON. And those are good things. I am not being negative, but you would tend to benefit, financially, which is not a bad thing, if some of these things that you predict, if we implement policies to try to prevent some of the things that you predict from coming true.

Mr. STERN. I am getting involved in things which I think are very good ideas. I have described exactly what my interests are.

Mr. BARTON. Totally acceptable. I just want the record to show that you have economic interests outside of the academic interest.

Mr. STERN. They are indeed on record in the House of Lords.

Mr. BARTON. I understand that. Now, I want to ask you about this 5 degree centigrade increase from preindustrial levels. The first question is just very, very mathematical. What is 5 degrees in Fahrenheit? Is it about 10 degrees?

Mr. STERN. No, it is 9. Multiply by 9/5.

Mr. BARTON. OK, 9 degrees. Now, what is magic about preindustrial level temperature? Is the assumption that is the perfect temperature?

Mr. STERN. Not at all. I was trying to describe—should I ignore this?

Mr. BARTON. We are not trying to irritate you. That says we have got a series of votes.

Mr. STERN. I thought it might have been something I said.

Mr. BARTON. No, sir.

Mr. STERN. There is nothing magical about preindustrial times. It is just a marker against which you can measure change. So when I was talking about 5 degrees centigrade above preindustrial times, I was saying imagine a world at that particular temperature, what does that world look like?

Mr. BARTON. But you are not stipulating that that is the perfect temperature?

Mr. STERN. Not at all, no.

Mr. BARTON. OK, now, is 5 degrees centigrade or 9 degrees Fahrenheit increase universal? I mean are we going to have temperatures increase 9 degrees Fahrenheit in southern Virginia and also in northern Wales, or does it vary around the world, and is the impact identical, or is there a different impact in certain regions?

Mr. STERN. There are different impacts around the world. These global averages across land and sea, so one difference would be you would expect rather bigger increases over land than over sea. You would expect bigger increases toward the poles, for example. You would see very differential impacts. Some parts of the world would dry right out. It seems that Southwest Africa is drying out, and the eastern part of Africa is getting wetter.

Mr. BARTON. But is it fair to say that assuming there is a temperature increase, and I will stipulate that we have certainly proven that there has been a temperature increase, that the temperature difference is going to vary by region and the impact is going to be different by region. Is that a fair statement?

Mr. STERN. It is a fair statement, but it is also important to recognize that the impact of temperature increases are largely through water in some shape or form—storms, floods, droughts, sea level rise—and that is dependent on the whole structure of the planet's atmosphere. You can't look at the impact by just looking at temperature in one place, but there is no doubt that that will vary by place.

Mr. BARTON. OK, now I am down to 3 seconds, so my next question: the economists that have criticized your economic analysis, which I stipulate that you are an expert—I am not casting any doubts about your economic background—have primarily centered on two things. They have centered that you either had no net present-value-discount rate, or if you had one, it was very low; and number two, that most of the negative consequences in your own work are fairly far out, if I remember correctly, after 2200, and if you had the proper discount rate, the net present value of that today wouldn't be nearly as large as you show it to be. Can you comment on those criticisms of your economic methodology?

Mr. STERN. Certainly, the attitude that we bring to the evaluation of benefits in the long term, relative to benefits now is clearly a key issue here, because precisely the way in which I opened up my testimony and much of what we have done in the past is going to determine what happens in the next 30 or 40 years, so our actions now have the consequences, and I have argued very big consequences, rather further down the tracks. It is quite clear from the logic of the exercise that the way you treat future consequences relative to consequences now is very important.

It is not true to say there was no discounting. That is simply false. What I did not have, and gave explicit arguments for, is pure time discounting. Now, this is a technical subject, but I would like to try to explain what pure time discounting means.

Mr. BARTON. You have got my permission. I am all for being technical. I love being technical.

Mr. STERN. Let me try to explain it without being too nerdish and heavy. Suppose we had a pure time discount rate of 2 percent. That would mean that if you run that forwards, say, for 35 years, it would mean that we would give a weight to somebody born in 2005 half of that of somebody born in 1970. Given by assumption for this part of the argument that we suppose they have exactly the same pattern of consumption over their lifetime, it is not an issue of one group being rich or one group being poor. Pure time discounting is actually to discriminate by date of birth, to attach directly lower weight to somebody born in the future, and 2 percent per year is big. It means half the weight. So those of us who have children——

Mr. BARTON. But that is what we do in most economic analysis.

Mr. STERN. No, not necessarily. We discount in many ways because we think that future generations will be better off than we are, unless we take the ethical view that an increase in a real dollar to them, forgetting about inflation, would be worth less than now to us because they are richer. That is central to the analysis of the Stern Review. It also means, of course, that if we take action now to make that generation much worse off, then on that logic, we should have a higher weight on an extra dollar that occurs to them. So what that underlines is we have to think through those ethical issues, because what we are dealing with is changes in the long-term future, and very big changes.

And this is the second technical point I would like to make about discounting: discounting usually refers to small movements around the path. In other words, you build a bridge. It costs you a bit now. It gives you benefits down the track. And you try to compare the cost now and the benefits down the track. But essentially, you have not rewritten the American economy or the British economy. It is a small change from the perspective of the economy as a whole. This is not such an issue. This is an issue about very big differences, potentially in growth rates, and very big risks, and you have to build that directly into your analytical framework.

Now, there is a third point here, which is also technical, which is this not about simply an aggregate consumption good. We are talking about environment and other sorts of consumption, and there are many more dimensions that we should think about. What we are talking about is we hope rising consumption, we hope, and you would discount for that reason. But you may also, and we fear, have strongly deteriorating environment. If you then said, well, I could invest in things other than climate change, and as to when these problems manifest themselves, I am going to spend the money, the returns on that investment, in sorting out those problems when they happen, what would you find? You would find that the price of taking action would have moved up against you very sharply for the kind of reasons that I described. So a third logical problem, an error that many people have made in this analysis, is to see this as just a one-good problem, as opposed to key aspects of the problem having different goods.

Now, I am sorry to have been slightly technical. And the paper, the American Economic Review, that was published in May of this year is even more technical. But I did want to explain that these issues have their complexities. We can tackle them. But I also have my view that some of the discussion in the literature has not really recognized the big studies, analyses, and literature on this issue, and has taken a very simplistic approach.

Mr. BARTON. My time has expired. I want to commend you for trying to be technical and trying to quantify. I happen to disagree with your methodology, but at least you have attempted to put it into a substantive form that there can be a debate on. And I think that is very important because the consequences of actions that we are asked to take at the governmental level, both domestically and internationally, are huge. And so at least you have tried, using your economic background, to put some parameters on it. And while I disagree with the way that you have done it, I totally respect that you are trying to do It, and I commend our chairman for asking you to be a witness. And at some point in time, I would love to have off-camera, a very technical discussion with you because I think it would be illuminating, at least for me. Thank you, Mr. Stern.

Mr. BOUCHER. Thank you very much, Mr. Barton.

Mr. STERN. I would be very happy to have that. Thank you.

Mr. BOUCHER. The subject of discounting future harm to present value was sufficiently important that it was worth taking this extra time in order to illuminate it.

We have a series of three recorded votes that are currently pending on the floor of the house. We have approximately 4 minutes for the members to respond to those. The response will take a little more than one half-hour. And as much as I regret having to recess the subcommittee for that purpose, and ask Lord Stern to stay with us, I am afraid we have no alternative.

And so the subcommittee does stand in recess, pending the completion of the third vote, and we will reconvene immediately thereafter.

[Recess.]

Mr. BOUCHER. We will at this time reconvene, and I am please to recognize, at this time, the gentleman from Texas, Mr. Gonzalez, for 5 minutes of questions.

Mr. GONZALEZ. Thank you very much, Mr. Chairman. Welcome, Lord Stern. We truly are appreciative of the insight that you provide us. A couple of observations, and I think I do want to stay, probably, in pretty general terms in my questioning to you.

I think that one of the biggest challenges that you and others that believe as you do have when you come before members of Congress, especially the House of Representatives, is that we are simply hardwired to think in 2-year cycles. And if you can overcome that, and have us look beyond that, and sometimes political interests and such, you may be successful. Few people have been able to succeed in that. And it also seems that any of our efforts that we have initiated, even here on the Hill, and I will give you a couple of examples that you might find rather interesting, have been somewhat frustrating experiences.

FutureGen, were you familiar with that particular project, Department of Energy and such? Well, it seemed we had a lot of competition for that. That was a way, obviously, that we were going to have coal-fired plants and such, sequestration, and capture and such. We gave up on that because of the cost. Here on the Hill, we have our own power plant, and we thought we would try to increase the use of natural gas to cut down on emissions, but if I remember, we operated about 42-percent natural gas and maybe increasing it all the way to 15 to 16 percent more natural gas. It is costing us anywhere from $1 to $1.8 million. And that is easy for Capitol Hill to absorb some of that costs for the obvious reasons, but if I went back to San Antonio and told my municipally owned utility to do the same thing, and that is utilize natural gas in a greater degree than they use now, and to pass on that kind of cost to the ratepayers, I understand that, politically speaking, that is a difficult thing to do. We try to buy carbon credits and such here on the Hill, because we think that somehow it is going to encourage better habits out there that will reduce carbon emissions, and we find out that it probably didn't change behavior at all.

So we have some very real-life experiences here that have been somewhat frustrating. But on top of all of this is something that you observed, and I think some of the members here are very sensitive to it, and that is why the United States, why Great Britain, when we have the other countries such as India and China, in essence, saying, well, we are going to wait until you do it.

And I know that you have advanced this basis and reason for discounting, present costs now, future savings later, which is a very difficult principal many times in the political arena, and I am going to agree with you. I really do believe that. The question to you is if we adopted certain of the practices that you are advancing that will demand tremendous investment by our government, maybe altering, to some degree, a lifestyle of the citizen, some sacrifice, some pain, and the same is true of Great Britain, is it an economic suicide pact to our people? Because that is basically what people are advancing to counter what you have to say today, what is the implication? How dire? How serious?

Mr. STERN. We have to be analytical, and we have to look at the difficulties. When you do look at the costs of cutting back, and you think about how to do it well, energy efficiency, of course, saves you money. Avoiding deforestation, if it is done well, need not be costly. Investing in new technologies, using the technologies we have better, that is, in very general terms, the kind of things that you can do. Some of them do save money.

But many of them cost, and I and many others have to, as best we can, make an estimate of the cost of cutting back on emissions to a degree that would allow stabilization at 500 parts per million, and we, it is not just me, have come up with numbers around two percent of GDP per annum for stabilizing at 500, perhaps one percent of GDP per annum stabilizing at 550, if we have good policies. And there are quite a few ways to mess this up and make the costs higher.

So I think the first attempt to grapple with your question, which is a very important one, is just to try to be quantitative about the costs, and in being quantitative, to be specific and realistic about the potential of different kinds of technologies. McKinsey's have done that since the report was published, the International Energy Agency in Paris has done a lot of work on that. The IPCC has done a lot of work on that. And we did try to do it ourselves in the Stern Review.

So working bottom-up, looking at the kinds of measures you would have to take in cutting back on the scale that we described, those are the kinds of numbers that we came up with. Is 1 or 2 percent of GDP economic suicide? The answer is no. It is 1 or 2 percent of GDP, which is real resources, and I don't want to dismiss it or say it is insignificant. It is not insignificant. The argument is that it is a small insurance premium to pay relative to the risks you remove in the future. Or if you want to get quantitative about the costs of the inaction, it is relatively small relative to those costs.

You have to be careful with words like suicide, but I think it is much more dangerous not to do these things than it is to try to do them. But policy matters enormously, and good policy matters enormously. I think that people will understand why it is being done, and I think that if you design these things in a way that, for example, return revenues from taxes or return auctioning of permits back to people in different ways, and you can concentrate those on research, you can concentrate them on compensating poorer parts of the population for the price increases, then, I think that you can put together policies that will make it easier to bring people along. But I do not think that an increase in cost of 1 or 2 percent, like a one-off, permanent increase in costs of 1 or 2 percent, I don't think that can be described as economic suicide. Real resources, resources that matter, but not economic suicide.

Mr. GONZALEZ. Thank you very much, Lord Stern, and I yield back.

Mr. BOUCHER. Thank you, Mr. Gonzalez. The gentleman from Kentucky, Mr. Whitfield, is recognized for 5 minutes.

Mr. WHITFIELD. Thank you, Mr. Chairman and Lord Stern. We appreciate very much your being with us here today.

First of all, I wanted to make a comment about this New York Times article that talks about the European cap-and-trade system, and it said implicitly in 2006 and 2007, the first 2 years of operation of the European cap-and-trade system that CO_2 emissions were higher than they were prior to that. So the purpose of the cap-and-trade system was to reduce CO_2 emissions, and in fact, they have been higher. Would you make a comment about that?

Mr. STERN. The cap-and-trade system in Europe is young. The first phase ended at the end of 2007, and the second phase has already started. The price of carbon dioxide in the second phase now is around 25 Euros or $30 a ton.

Mr. WHITFIELD. Forgive me for interrupting. I don't want to be rude. We have these time constraints. But would I be correct in saying that, yes, the CO_2 emissions were higher in 2006 and 2007 than they were before?

Mr. STERN. Yes, they gave away too many permits and that is one lesson which I think has been learned.

Mr. WHITFIELD. And you hope in the future that you will be able to correct those problem and be able to make the CO_2 emissions less.

Mr. STERN. Yes, you can recognize the problems and see how to correct them: give away less permits.

Mr. WHITFIELD. Now, recently we met with a group of Chinese, and I know we had a lot of discussion about China and India, and they indicated that within the last 3 years, in each of the last 3 years, the amount of electricity produced in China from a new coal technology, producing electricity, new coal plants coming online in each of the last 3 years, exceeded all of the total electricity produced in Great Britain in each one of those years, which is an unbelievable figure. And I was just curious, in Great Britain, what percent of electricity is produced from coal?

Mr. STERN. The Chinese population is 20-something times that of the U.K., and it is growing very much faster, so that figure isn't particularly surprising. I don't have the U.K. coal figure in my head. I guess it is around 25, 30 percent, but I would prefer to communicate that later, because I don't have it.

Mr. WHITFIELD. Would you have any idea about Europe as a whole, what percent of all of Europe's electricity is produced from coal?

Mr. STERN. I am guessing 35, 40 percent. But again, I would want to be a little careful about that and would not want those numbers, particularly, on the record. I would prefer to come back to you.

Mr. WHITFIELD. The purpose of this hearing and series of hearings is looking at the costs of not doing anything versus the cost of doing something, and I was reading this article, they said you had quoted in your review Professor Richard Tol 63 times, who is supposedly one of the leading environmental scientists in the world, and he said that you really did overstate the damage of not taking action. He said that you really cherry-picked and picked the very worse choice out of every opportunity. And then Robert Mendelssohn, the economist up at Yale said that you were way too optimistic, that the cost of taking action to solve this problem would be only one percent of gross domestic problems. How would you react to their criticism?

Mr. STERN. I think both of those gentlemen are wrong. And when we worked out the cost of action, we did it in a bottom-up way, in looking at the different kinds of actions you could take, in carbon capture and storage, going into the future, wind and so on, renewables, and we built it up as best we can. Subsequent work, as I said, McKinsey's work, has actually come out pretty well where we have, so that is on the Mendelssohn criticism. I just have to refer you to the other studies after ours.

On the Tol criticism: it is completely wrong. I have explained in my testimony why it was I think we underestimated. The emissions are growing faster than we assumed. The carbon cycle seems to be getting weaker. The absorptive power of the planet is less than we thought. I think that the idea that somehow we overstated that case by cherry-picking is shown by subsequent experience, analysis, and evidence to be completely false.

Mr. WHITFIELD. Well, you understand the dilemma that we are in. We get different views on the damages of not doing anything, versus the costs of doing things. Here in America, 52 percent of our electricity is produced from coal, and what is going on in China and elsewhere and most of these cap-and-trade systems are biased against coal. But one question I would like to ask you, what is your best guess as to when the technology will be available to have an effective carbon-sequestration program?

Mr. STERN. The answer for that is very much in our own hands, and if we are slow, then it will take much longer. I think the fastest we could get really strong evidence and experience and show what works and what doesn't on a commercial scale is probably 7, 8, 10 years, but only if we move ahead very strongly and get those demonstration plants at commercial scale up and running, and I think public money has to get behind that in order to share the risk and share the cost. It will be much longer if we don't get on with it.

Mr. WHITFIELD. And you do think it is absolutely necessary that we do it?

Mr. STERN. I do. It is a reality that coal will be used, and we have to try to use that in as clean, efficient, safe way as possible.

Mr. WHITFIELD. Thank you.

Mr. BOUCHER. Thank you very much, Mr. Whitfield. The gentleman from Massachusetts, Mr. Markey, is recognized for 8 minutes.

Mr. MARKEY. Thank you, Mr. Chairman, very much, and thank you, Lord Stern, for your outstanding analysis and your service to the planet. You are one of the world's great citizens. Thank you.

You have worked to quantify the economic impacts of failing to address global warming, which are staggering. Can you expand on the human face of these costs? What do the impacts mean in terms of lives lost, human suffering, both in places like Africa and Asia, but also here in the United States? Can you put a human face on this?

Mr. STERN. It is difficult to put a quantitative human face, but we can describe the kinds of events and get a feeling for how big they are. I mentioned in the discussion earlier today the consequences of the retreating glaciers on the Himalayas for flooding in Bahia, where the death toll last year was very high. I am sorry I don't have the number in my head, but again, that is available. The potential consequences of the disruption of the North Indian monsoon would be really devastating to hundreds of millions of people in North India. A meter or so of sea level rise would be extremely difficult for cities ranging from New York to Cairo, Dhaka and so on, around the world. It is flooding, it is droughts, it is the intensity of storms and hurricanes. We saw in Myanmar recently the human cost of the recent typhoon, sadly magnified by the inappropriate reaction. It is these kinds of events which completely disrupt people. And ultimately desertifying, some parts of the world submerging, some parts of the world subject to uncontrollable floods, you would see massive movements of populations.

The examples I gave at 5 degrees centigrade are about rewriting where people can live and the cost of that movement and the conflict that history has told us would likely ensue. That is the kind of human cost. You can talk about malaria and other water-borne disease and so on. You can talk smaller things like the need to air condition the London Underground. That is not to be a big deal, although it happens to be rather expensive. You can talk about the snows disappearing off the Rockies and what that means for California's water. There are a whole range of things like that, which are very important in human terms, but less traumatic than the ones I described.

Mr. MARKEY. Thank you. My colleague Mr. Upton and others have argued that it would be more cost-effective to address the symptoms of global warming instead of the disease. In effect, they say we should adapt our way out of this. Can you respond to that argument?

Mr. STERN. Adaptation is going to be important. We are already seeing the consequences of 0.8 degrees centigrade, and however responsible we are, it is rather likely that we are going to experience another one-and-a-half or two degrees centigrade, and you can see that the adaptation cost of that will be very important.

So adaptation is a fundamentally important issue. But adapt your way out of it, if I understand that term, and it is a term that is often used, seems to suggest that somehow by pulling a few levers, you can get back to something like the lifestyle that you used to have. Well, the kind of big movements of population that I have described, and the conflict that could ensue, I think it is clear that adaptation is not the kind of thing that you would describe as easily getting back to the lifestyle that you had before. So in that sense, there are limits to adaptation, but it is absolutely clear we will have to adapt. I don't want to mitigate this or that. We are going to have to do a lot of both.

Mr. MARKEY. But adaptation is not a substitute for mitigation?

Mr. STERN. Absolutely not. You could not seriously describe the kind of migration and conflicts that are likely to result from getting to 5 degrees centigrade as simply adapting to changing circumstances. It doesn't seem to be a very good description.

Mr. MARKEY. And now that the scientific debate over climate change is largely over, although there are outliers out there still battling, like Japanese soldiers still on islands in 1952 or 1953, but the scientific debate is largely over, the debate is turning to largely discussion over the costs of dealing with this issue. The Senate debate on the Lieberman-Warner bill largely devolved into a battle of economic models, but these models have consistently overstated the costs of environmental and consumer protection and underestimated or ignored the costs of doing nothing. What prospect is there for improving these economic predictions, that is the cost of actually inventing these new devices, these methods of energy that fuel our economy and as a result lowering the overall economic projections of the harm to the economy?

Mr. STERN. First, I agree with you that the scientific debate is essentially over, in the sense that I think it is very clear that climate change generated by humans is there, and it is a major issue. Obviously, there would be debates and there should be, how big are the risks? But in terms of what humankind is doing and the magnitude of the risks, I think that debate is over. I am sure that you and I would both defend the rights of people to join the Flat-Earth Society and speak up and say that the Earth is flat. It is a free country, and that is their right to do it. They just don't happen to be terribly convincing, and I think that is the same position now on the climate change story.

On how good are we at economic forecasting, broadly, the answer is not very, but that doesn't mean that we have nothing to say. I think the costs of action, the analytical basis of the cost of action, through close examination of the kinds of technologies we have, what they cost and so on, I think that is reasonably well founded. We do know quite a lot about the cost of wind power. We have more to learn, but we are learning about the cost of carbon capture and storage. We know quite a lot, from experience, about the cost of nuclear. So I think that scenario, where we can actually be quite confident the estimate that we have, provided, of course, we offer a range, so when I say one percent of GDP for 550, I think that stabilizing at 550, you know, you are going to have to take plus or minus one or two, higher if policy is bad and technically progress goes slowly, lower if it is the other way around. So I think we can start to get a feel for where these ranges are and the kinds of errors that are likely to be made.

Also, I want to underline that this kind of analysis is quite young. It is only really over the last 3 or 4 years that there has been tremendous focus in the political and the analytical arena on this area. There has been, in the past, quite a lot of work, but the intensity has leapt up in the last 3 or 4 years, so I am optimistic, in answer to your question, that we will get rather better over the next 5 years.

Mr. MARKEY. I think you are right, and I appreciate the chairman's indulgence. AT&T, in 1980, believed that there would be one million people using cell phones in the year 2000 in the United States. I think that there tends to be an underestimation of the ability of technology to transform society over the long run, and we are seeing that.

But on the other hand, it took until 1990 for the Vatican to apologize to Galileo, so I don't know how long we will have to wait for apologies to Jim Hansen, another scientist, and move on, then, to what the consequences are to these scientific discoveries. I thank you, Mr. Chairman.

Mr. BOUCHER. Thank you very much, Mr. Markey.

We are honored to have as a member of the subcommittee the Minority Whip of the House of Representatives, the gentleman from Missouri, Mr. Blunt, and he is recognized now for 5 minutes.

Mr. BLUNT. Thank you, Mr. Chairman. I will admit the Flat-Earth Society comment got my attention. Since we are there on that topic, was there ever a time that there wasn't climate change that you are aware of? Haven't we always had climate change?

Mr. STERN. Yes, indeed. There are lots of factors involved, oscillations in the solar energies coming in, explosions of volcanoes, these kinds of things. There are many natural effects which are important.

Mr. BLUNT. And I think you don't have to be particularly perceptive to accept the fact that we have always had climate change, nor do you have to be particularly knowledgeable to know that a generation ago, everybody was talking about the climate cooling in the '70s. That has not turned out to be the case. I agree with you that it ought to be dealt with in the best way, but it also ought to be seen as part of the cycle of the Earth, as it is, and how you deal with that is an important thing.

I only really had one question Mr. Chairman. I don't think I will take my 5 minutes. Looking at your report, today world oil prices is around $140 a barrel. What was the price point when you did your report?

Mr. STERN. We published at the end of 2006. I would guess it would be $50, $60 a barrel then.

Mr. BLUNT. And in talking about what it takes to induce technological chance, how would you factor in the price-point factor, now, differently than when you wrote you report, the impact of $60 a barrel oil on all of these issues, versus the impact of $140 a barrel oil, how do you see that Lord Stern?

Mr. STERN. In some ways, it makes the cost of switching over away from fossil fuels to other kinds of things cost less, because you are comparing a higher cost of doing it through fossil fuels with the cost of doing it in other ways which has not moved so much. I haven't redone the numbers, but that effect would be to push down the cost.

It does, of course, make some of the politics more difficult, because you are talking about carbon taxes and cap-and-trade in the context of prices for fuel that have gone up. So I think there are, in some respect, greater political difficulties, but the economic argument for switching over to other things is strengthened by that.

Mr. BLUNT. Would I be right in assuming that the economics of a cap-and-trade system to where you use that system to encourage technological shifts, some of that should be offset by what has happened now in the economy to the cost of oil and other fuels? Would that be correct?

Mr. STERN. That is absolutely right. It does have the momentum in that direction, but there is still the case that there is market failure. There is a damage that they are doing when they consume those fuels, which, unless there is policy, the market doesn't face them with, and that is why a cap-and-trade scheme is important, because it is correcting a market failure, even in the context of high fuel prices.

Mr. BLUNT. I will ask one more question because I am learning some things here that I need to know. Why would it be that the cap-and-trade penalty would produce a behavioral change difference than just the marketplace penalty of fuel costs that are two-and-a-half times as high as when you wrote you report?

Mr. STERN. They have quite strong effects in similar directions, but let me just differentiate the two, because in many ways they are the same, but they are not exactly the same. If you think of carbon capture and storage for coal, coal prices will go up with the other fossil-fuel prices, and to that extent, other fuels will become more attractive relative to coal. But it will still be true that carbon capture and storage for coal will be more expensive than not doing carbon capture and storage for coal. So in order to induce people to switch from ordinary coal to carbon capture and storage for coal, you do need a price for CO_2, and that could not be achieved simply——

Mr. BLUNT. By the marketplace?

Mr. STERN. Yes.

Mr. BLUNT. Thank you.

Mr. BOUCHER. Thank you very much, Mr. Blunt. The gentleman from Washington State, Mr. Inslee, is recognized for 8 minutes.

Mr. INSLEE. Thank you, Lord Stern, and thank you for your international service. It is very much appreciated.

I want to make three points. First, the European experience, you noted that there were too many permits issued, and our study in Europe indicated that they essentially had some bad data, because they got some bad data from the applicant, if you will, and I want to point that out to some of my colleagues, because Tammy Baldwin and myself are endeavoring to pass a bill this year that will start the registration process this year so that we can gather good data even before we implement the cap-and-trade system, hopefully in 2009. And I just want to emphasize your testimony in that regard about the importance for us to get good data when we start, and we want to start that process this year, so thank you for bringing that up.

In your report, you talked about a couple of mechanisms for increasing clean technology research and development, and you addressed something we call a renewable portfolio standard, and a second something you call in Europe a feed-in tariff. I just want to let you know, I am introducing, with some of my colleagues today a bill that will essentially implement a feed-in tariff system in the United States. It is a called the Renewable Energy Jobs and Security Act, because we think that will promote jobs and security. I noted in your report that in evaluating those mechanisms, you concluded that both had been proven effective in the European experience, and concluded that the feed-in tariff, which essentially is a guaranteed price for clean electricity, was the most economically beneficial, most efficient mechanism. That is heartening, because you were here today, and we are introducing our bill today, so it is a happy coincidence. I just wondered if you may comment on why that is and what your findings were in that regard.

Mr. STERN. I think it is largely to do with the importance of clarity in long-term planning for investment decisions, and a feed-in tariff does give the person making the decision, for example to invest in solar, competence in the long-term price that they will get in return on their investment. In electricity, they will get their investment. Of course, there will be revision clauses in those contracts, but the revision clauses are transparent, too, or else there will be some uncertainty resulting from that. The investor has an understanding of what that is.

I think when you have renewable portfolio standards, that isn't quite so clear. The price you are going to get, a lot depends on exactly how those standards function, and I think there is greater uncertainty involved for the investor in that. So from the point of view of transparency and clarity for all of those involved I would share your preference for feed-in tariffs. And on your previous point, I would strongly recommend that in putting your policies on cap-and-trade in place, you learn from some of the mistakes we made in Europe.

Mr. INSLEE. We intend to go to school, and I would love to add your name as a cosponsor of my bill, but we just don't allow Lords to cosponsor bills in the House, so that is the one handicap we have.

I want to test-drive a theory that I have on the ultimate benefits of a cap-and-trade system. There really are two parts, in my view, of a cap-and-trade system. One is it is a self-restraint on one's own national contributions to CO_2 loading, which is beneficial. But I really believe it is a more important of industrialized nations, particularly the United States' adoption of one to the extent of which it drives clean energy research and development, because ultimately, even if the United States restrains itself to zero CO_2 emissions, unless the Chinese and the Indians of the world have access to new technology, solar-thermal, enhanced geothermal, sequestered coal, you name it, unless they can have access to that technology, we are all toast. And so I really believe that the more important part of a cap-and-trade system is to drive investments to develop these clean-energy technologies, which frankly we can sell, to the extent that they are not pirated to the developing world.

So my view is we get a self-restraint, but a self-development is actually a more important reason for having a cap-and-trade system, ultimately, when it comes down to the world's CO_2 loading. That is a theory I wan to throw out. I just appreciate your comments on the thoughts.

Mr. STERN. Cap-and-trade with auctioning permits and with carbon taxes are in some ways quite close, but there are important differences. Cap-and-trade gives you clarity on the quantity. You are much more sure about the overall emissions you are going to be making, but of course, there is some uncertainty on the price. A tax gives you the greater certainty on the price of carbon by the tax, but it gives you greater uncertainty on the quantity, and I think uncertainty on the quality is worrying in this context where we have to move quickly.

Secondly, on cap-and-trade, you have the advantage that if you open up to trade elsewhere, you not only bring your costs down or get more emissions reduction for the money, for the usual reasons that international trade allows you to buy where the product is produced most cheaply; but also, you have a chance to bring the developing world much more strongly into the story because they will recognize if they have very cheap ways on cutting back on emissions, they can get resources on the carbon market to help make that happen.

So I think it will be a very important part of the glue of a global deal. So cap-and-trade, if opened up in the right way to international trade, does enhance the prospects of the global deal in a way that I don't think carbon tax does. You could fix it so that a certain amount of the revenue is promised and so on, but I am not sure that that would be credible, because that would be the government transfers, rather than the private sector buying those reductions on the market. So those two reasons, clarity and quantity and their role in international trade, I think cap-and-trade does have some advantages.

I think, in its driving of R&D you could argue that tax on carbon drives R&D also, but I do think a cap-and-trade with clearly announced future reductions of the kind that you have been discussing in your bills does actually give the greater, and I think people have greater confidence in that environment about what they have to plan for. Now, governments under pressure can change taxes. Long-term plans, which everybody in the industry is plugged into, where everybody knows where they are going, I think, are more robust to short-term political pressures, and that is very important in this context.

Mr. INSLEE. Well, you just reminded me about another lesson from Europe. When we talked to the European folks, they repeatedly stressed that a cap-and-trade system was not a silver bullet and had to be a part of a coalition of other mechanisms, including feed-in tariffs, including efficiency standards, including good public transportation systems, including good public planning of our growth and the like. And their message to us was don't think a cap-and-trade system is going to be the only thing. You have got to have a panoply of these things to address the issue. Would you share in that?

Mr. STERN. I definitely would, and I would add to that list strong public support for research and development.

Mr. INSLEE. Wholeheartedly. Ours is pathetic. We are going to increase it dramatically, I hope. Thank you for your testimony and your work.

Mr. BOUCHER. Thank you very much, Mr. Inslee.

Well, Lord Stern, this has been most illuminating for us. I am sorry. Mr. Shimkus has arrived. I didn't see you.

Mr. SHIMKUS. I know you were trying to sneak away.

Mr. BOUCHER. We are delighted by your arrival, and you are now recognized for 5 minutes, the gentleman from Illinois.

Mr. SHIMKUS. And I apologize. I can give you a fair accounting of my locations since I left. Ninety members of the Future Farmers of America had to get into the Capitol, and that with one of our NASA astronauts just in the office, and of course we cast three votes, so that is the life of a member of Congress here, and we apologize because we do appreciate your attendance here.

Let me ask you a question that has been bothering me. Sir Isaac Newton established the fact of gravity. And all of this debate on climate change, and Chairman Dingell mentioned it today, it is the consensus of the scientific community. Why is it not a fact?

Mr. STERN. I have great respect for Sir Isaac Newton, but he established a law of physics that holds under certain circumstances. It doesn't hold at the level of nuclear physics, so I think any law of physics applies to a description of certain kinds of circumstances. I don't want to be a linguist logic chopper, but I wouldn't call it a fact. I would call it a law of physics, applicable to certain kinds of circumstances.

Now, the laws of physics for climate change, and please, I did math and physics as undergraduate: I am not a scientist. I am here as an economist.

Mr. SHIMKUS. There are very few scientists here either.

Mr. STERN. I listened to the scientists very carefully in doing the work, but I am not a scientist. But if I understand this well, the science at this story started with Fourier in the 1820, the famous French mathematician and physicist, and he did a heat balance of the world, looking at what was coming in and what was going out, and he was puzzled because the world turned out to be rather warmer than he thought, and that led him to the idea of something being trapped. In the middle of the 19th Century, they worked out, a British scientist, particularly, Tyndall, worked out what it was that was doing the trapping, and by the end of the 19th Century, Arrhenius, a Swedish chemist, got the Nobel Prize, really, in part for his work, did some calculations on how big these effects were.

So what I want to emphasize here in response to your very important question is this is 19th Century simple science. Now, what we have had since then is much greater quantification, more detailed modeling of the very complex structure of the atmosphere and so much, which has added greatly to that work, and in recent years has given us a feel for the probabilities, and it is only if you got a feel for the probabilities that you can start to get quantitative on the risk.

So that is the way in which I understand that the science has developed and the way in which the laws of physics and chemistry have been folded into this, but I am not a scientist.

Mr. SHIMKUS. And I appreciate that. I think that part of the problem for a lot of us is that it is a consensus of the scientific community that it is manmade emissions that is the primary driver of this when there are so many other variables that are really never discussed or talked about. Ranking Member Barton always talks about the evaporation aspects.

Are you familiar with the Argus buoys that are measuring the temperature of the ocean through different depths as they have been deployed over the past years?

Mr. STERN. I am aware of that work, but I am sorry, sir, I don't really know much about it.

Mr. SHIMKUS. The Argus buoys have disappointed global-warning alarmists in that they have failed to detect any signs of eminent climate change, from measuring the change of the ocean through the currents at the different levels.

There are a couple other things, and I want to be quick. Some people say to get to where we want to go, it is going to cost $2.50 per ton. You have expounded the cost of inaction is $85 a ton.

Mr. STERN. I have tried to focus in most of the work on the marginal cost of abatement, how much it costs to get rid of the extra ton. And then on the kind of paths we are thinking about, that might be $40 or $50 a ton of CO_2. You then have to compare that, and I think one of your colleagues referred to this earlier, what you think is the marginal damage of a ton of CO_2. That is enormously sensitive, and I lay this out carefully in the Ely lecture that I referred to before, the one published in the American Economic Review last month. That is extremely sensitive to the assumptions you make, and in particular, varies greatly across the path. So the more responsible you are in bringing down the emissions, then the lower that cost will be.

Mr. SHIMKUS. And if the chairman will allow me, Chairman Boucher, I will be real quick, and I apologize for running over my time, I just want to present a premise. You mentioned also about the cap-and-trade, and you also talked about a carbon tax. If we move in this direction, I would like us to be intellectually honest with the public, because the public has to make a decision because there are going to be increased costs. And what is intellectually honest and really easier on the balance sheet is the tax and a portion of the revenues to the solution, versus this cap-and-trade regime, which is a design regime to really confuse the public that there is actually a cost as the cost is passed on by other methods.

I think Chairman Dingell had mentioned that at first. Of course, that is part of where I will come because we have to convince the public, and then they have to be willing to accept increased costs, whatever they may be. And I know that in Great Britain, in an article by Colin Brown, deputy political editor of the Independent, on the 2nd of May, more than seven in ten voters insisted that they would not be willing to pay higher taxes in order to fund projects to combat climate change, according to a new poll. And this is a Kyoto-regime accepted country. I met with some British parliamentarians from Scotland, coal regions. The GDP debate is across the board for a specific country, but what happened here in the Clean Air Act, as I have mentioned here in the committee, and I have talked to my environmental friends on the left, yes, you may apportion a moderate increase across the board, but there will be areas of the country that will be greatly disadvantaged in movement in this, and that is where a lot of us will be fighting for a fairer application across the board.

Thank you, Mr. Chairman. You have been very gracious. I yield back my time.

Mr. BOUCHER. Well, thank you very much, Mr. Shimkus. And Lord Stern, we appreciate very much your testimony here today which has been illuminating for all of the members. I think you could see from the range and depth of the questioning, the level of interest that we have in the work that you have done, and we are most appreciative to you. I think you can also see from the questions you received today that there is a somewhat more vigorous debate about whether we need to act on the subject of climate change in this country than exists in the U.K. and in most of Europe.

It was a pleasure having you here. We look forward to future conversations with you, and with that, you are excused.

Mr. STERN. Thank you very much. It was a privilege to be with you. Thank you all for your very thoughtful comments, and vigorous debate must be healthy. Thank you.

Mr. BOUCHER. Thank you, Lord Stern.

We turn now to our second panel of witnesses, and I would ask that they take seats at the table at this time. Ms. Sherri Goodman is the General Counsel of CNA, and the Executive Director of the CNA Military Advisory Board for that organization's project on national security and the threat of climate change. Dr. Anthony Janetos is the Director of the Joint Global Change Research Institute, which is a joint venture between the Pacific Northwest National Laboratory and the University of Maryland. He will testify regarding the effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States, recently released by the U.S. Climate Change Science Program at the U.S. Department of Agriculture. Mr. Jim Lyons is the Vice President for Policy and Communications for OXFAM American. And Dr. Roger Pilke is the Senior Research Scientist and Senior Research Associate at the University of Colorado in Boulder.

We welcome each of our witnesses. Without objection, your prepared written statements will be included in the record. We will now welcome your oral summaries. And Ms. Goodman, we will be happy to begin with you.

STATEMENT OF SHERRI W. GOODMAN, GENERAL COUNSEL, CNA, EXECUTIVE DIRECTOR, CNA MILITARY ADVISORY BOARD

Ms. GOODMAN. Thank you very much, Mr. Chairman and distinguished members. It is a pleasure to be here this afternoon. I appreciate the opportunity to testify before you on this critical and timely subject of climate change, and I will focus my remarks today on the national security implications of climate change.

As you noted, I am with CNA, a nonprofit analysis and solutions organization. I have been privileged over the last several years to work with some of our Nation's finest military leaders in their role as members of the Military Advisory Board, to which I am the executive director. Our project was established to examine the national security implications of climate change, and last year we produced a report on national security and the threat of climate change, and Mr. Chairman, I would ask that that report as well as my statement be entered into the record.

Our Military Advisory Board consisted of some of the most respected generals and admirals of recent times, including a former army chief of staff, former combatant commanders of both the Pacific Command and Central Commands for the U.S. Armed Forces. I have previously worked with most of these military leaders during the 8 years I served as Deputy Undersecretary of Defense for Environmental Security.

The CNA Military Advisory Board concluded that global climate change is and will be a significant threat to our national security. The potential destabilizing impacts of climate change include reduced access to freshwater for major populations, impaired food production, health catastrophes, especially from vector and food-borne disease, and land loss, flooding, and the displacement of major populations. What are the potential security consequences of these destabilizing effects? Overall, they increase the potential for failed states and the growth of terrorism, mass migrations, potentially leading to greater regional and global tensions and tensions over recourses, particularly water, are almost certain to escalate.

Let me briefly review the findings and recommendations of our work. The four findings of the Military Advisory Board are, first, projected climate change poses a serious threat to America's national security. The predicted effects include extreme weather events, drought, flooding, sea level rise, retreating glaciers, habitat shifts, and the increased spread of life-threatening diseases. As we noted in our report, these conditions have the potential to disrupt our way of life and to force changes in the way, keep ourselves safe and secure.

During the Cold War, Mr. Chairman, our Nation spent billions of dollars to protect Americans from the threat of nuclear attack by the Soviet Union. While the probability of such an attack was low, the consequences were so catastrophic that Americans judge deterrence of this threat a sound national investment. While it may be difficult to know the probability of catastrophic climate effects from possible tipping points, the potential consequences are such that prudent action is warranted today to reduce the change of such events occurring. Unlike most traditional security effects that involve a single entity acting in specific ways and points in time, climate change does not have a human face and has the potential to result in multiple, chronic conditions, occurring globally within the same timeframe. These potential threats to the Nation's security require careful study and prudent planning to counter and mitigate potential systemic failure. As noted by General Sullivan, Chairman of the Military Advisory Board, "As a military leader, you do not seek 100-percent certainty, because, frankly, we never have it. If you wait until you have 100-percent certainty, something bad is going to happen on the battlefield."

Our second finding is that climate change acts as a threat multiplier for instability in some of the most volatile regions of the world. Many governments in Asia, Africa, and the Middle East are already on edge in terms of their ability to provide basic needs, food water, shelter, and stability. Projected climate change will exacerbate the problems in these regions and add to the problems of effective governance. Economic and environmental conditions in already fragile areas will further erode as food production declines, diseases increase, clean water becomes increasingly scarce, and people move in search of more sustainable resources.

Third, projected climate change will add to tensions even in stable regions of the world. Developed nations including the U.S. and those in Europe may experience increases in immigrants and refugees as drought increases and food production declines in both Africa and Latin America. Pandemics and the spread of infectious diseases caused by extreme weather events and natural disasters, as the U.S. experience with Hurricane Katrina, may lead to increased domestic missions for a number of U.S. agencies, including state and local governments, the Department of Homeland Security, and our already stretched military, including our Guard and Reserve forces. Deployment of these forces comes at a cost to the American taxpayer.

And fourth, climate change and national security and energy dependence are a related set of challenges. Because these issues are linked, solutions to one affect the others. The path to mitigating the worst security consequences of climate change involve reducing global greenhouse gas emissions and putting our Nation on the path to more sustainable energy supplies.

There is a relationship between carbon emissions and national security. The more we can reduce our reliance on fossil fuels, especially those imported from countries that would do America harm, the more we can reduce the security cost America may pay later. The recommendations of the Military Advisory Board stress the need to take prudent actions to address climate change today to reduce national security threats and costs that could confront us in the future. Briefly, Mr. Chairman, our five recommendations are, first, that the national security consequences of climate change should be fully integrated into national security and national defense strategies, and as you probably know that included the recommendation which was enacted on the Defense Authorization Bill last year and the Intelligence Bill to produce a national intelligence assessment on climate change, which was released just this week and validates many of the findings of our work. Second, the U.S. should commit to stronger national and international role to help stabilize climate change at levels that will avoid significant disruption to global security and stability. Third, the U.S. should commit to global partnerships that help less developed nations build capacity and resiliency to better manage climate impacts. And fourth, the Department of Defense should enhance its operational capability by accelerating adoptions of improved business processes and innovative technologies that result in improved U.S. combat power through energy efficiency. And fifth, DoD should conduct an assessment on the impact of U.S. military installations worldwide of rising sea levels, extreme weather events, and other possible climate change impacts over the next 30 to 40 years.

Mr. Chairman, the threats posed by climate change can best be addressed, in my view, by the very qualities that make America a great Nation: leadership, innovation for smart solutions, and global engagement.

Mr. BOUCHER. Ms. Goodman, your time has expired by about 3 minutes now, so if you could, wrap up very quickly.

Ms. GOODMAN. All right, first, U.S. leadership is essential. We must lead in the fight against climate change if we are to retain our standing as a global power in the 21st century and begin the transition to lower carbon energy sources and more emphasis on energy productivity and efficiently. Second, we need to adopt sustainable energy strategies and solutions, and that applies as well to our military. It would greatly benefit from moving toward more sustainable energy sources.

[The prepared statement of Ms. Goodman follows:]

STATEMENT OF SHERRI GOODMAN

Chairman Boucher, Ranking Member Upton, distinguished members, I appreciate the opportunity to testify before the Energy & Air Quality Subcommittee of the House Committee on Energy & Commerce on the critical and timely subject of the national security implications of climate change.

I am Sherri Goodman, General Counsel of CNA, a non-profit analysis and solutions organization. I have been privileged to work with some of our nation's finest military leaders over the last several years in their role as members of the Military Advisory Board (MAB), to which I am the Executive Director. The MAB was established to provide advice on a CNA report, "National Security and the Threat of Climate Change," that examined the national security implications of climate change. Our Military Advisory Board consisted of some of the most respected Generals and Admirals of recent times, including a former Army Chief of Staff, and former Combatant Commanders of both Pacific and Central Commands for the U.S. Armed Forces. I have previously worked with many of these military leaders during the eight years I served as Deputy Undersecretary of Defense (Environmental Security).

I am also a member of the Council on Foreign Relations Task Force: Confronting Climate Change: A Strategy for U.S. Foreign Policy.

The Military Advisory Board developed a series of findings and recommendations as part of the CNA report. These findings and recommendations are relevant to the Committee's inquiry into the costs and risks of inaction on climate change.

Mr. Chairman, I request my statement and the 2007 CNA Report be entered into the record.

CLIMATE CHANGE IS A RISK TO AMERICA'S NATIONAL SECURITY

The CNA Military Advisory Board concluded that global climate change is and will be a significant threat to our national security and in a larger sense to life on earth as we know it.

The potential destabilizing impacts of climate change include: reduced access to fresh water; impaired food production, health catastrophes,especially from vector- and food-borne diseases; and land loss, flooding, and the displacement of major populations.

What are the potential security consequences of these destabilizing effects? Overall, they increase the potential for failed states and the growth of terrorism; mass migrations will lead to greater regional and global tensions; and tensions over resources, particularly water, are almost certain to escalate.

Let me review briefly the MAB's findings and recommendations.

The four findings of the Military Advisory Board are:

- **First, projected climate change poses a serious threat to America's national security.** The predicted effects of climate change over the coming decades include extreme weather events, drought, flooding, sea level rise, retreating glaciers, habitat shifts, and the increased spread of life-threatening diseases. As we noted in our report, "These conditions have the potential to disrupt our way of life and to force changes in the way we keep ourselves safe and secure."

During the Cold War, our Nation spent billions of dollars to protect Americans from the threat of nuclear attack by the Soviet Union. While the probability of such an attack was low, the consequence was so catastrophic that Americans judged deterrence of this threat a good national investment. While it may be difficult to know the probability of catastrophic climate effects, from possible tipping points, their potential consequences are such that prudent action is warranted today to reduce the chance of such events occurring. Unlike most traditional security threats that involve a single entity acting in specific ways and points in time, climate change does not have a human face and has the potential to result in multiple chronic conditions, occurring globally within the same time frame. These potential threats to the Nation's security require careful study and prudent planning—to counter and mitigate potential systemic failures.

As noted by General Sullivan, Chairman of the Military Advisory Board, "As a military leader you do not seek a hundred percent certainty, because frankly we never have it. If you wait until you have 100 percent certainty something bad is going to happen on the battlefield."

- **Second, climate change acts as a threat multiplier for instability in some of the most volatile regions of the world.** Many governments in Asia, Africa, and the Middle East are already on edge in terms of their ability to provide basic needs: food, water, shelter, and stability. Projected climate change will exacerbate the problems in these regions and add to the problems of effective governance. Economic and environmental conditions in already fragile areas will further erode as food production declines, diseases increase, clean water becomes increasingly scarce, and people move in search of more sustainable resources.
- **Third, projected climate change will add to tensions even in stable regions of the world.** Developed nations, including the U.S. and countries in Europe, may experience increases in immigrants and refugees as drought increases and food production declines in Africa and Latin America. Pandemics and the spread of infectious diseases, caused by extreme weather events and natural disasters, as the U.S. experienced with Hurricane Katrina, may lead to increased domestic missions for a number of U.S. agencies, including state and local governments, the Department of Homeland Security, and our already stretched military, including our Guard and Reserve forces. Deployment of these forces comes at a cost to the American taxpayer.
- **And, fourth, climate change, national security and energy dependence are a related set of global challenges.** As President Bush noted, now over a year ago in his 2007 State of the Union address, dependence on foreign oil leaves us more vulnerable to hostile regimes and terrorists, and clean domestic energy alternatives help us confront the serious challenge of global climate change. Because the issues are linked, solutions to one affect the others. The path to mitigating the worst security consequences of climate change involves reducing global greenhouse gas emissions. There is a relationship between carbon emissions and our national security. The more we can reduce our reliance on fossil fuels, especially those imported from countries that would do American harm, the more we can reduce the security costs America may pay later.

The recommendations of the Military Advisory Board stress the need to take prudent actions to address climate change today to reduce the national security threats and costs that could confront us in the future.

The five recommendations of the Military Advisory Board are:

- **First, the national security consequences of climate change should be fully integrated into national security and national defense strategies.**
- **Second, the U.S. should commit to a stronger national and international role to help stabilize climate changes at levels that will avoid significant disruption to global security and stability.**
- **Third, the U.S. should commit to global partnerships that help less developed nations build the capacity and resiliency to better manage climate impacts.**
- **Fourth, the Department of Defense (DoD) should enhance its operational capability by accelerating the adoption of improved business processes and innovative technologies that result in improved U.S. combat power through energy efficiency.**
- **And, fifth, DoD should conduct an assessment of the impact on U.S. military installations worldwide of rising sea levels, extreme weather events, and other possible climate change impacts over the next 30 to 40 years.**

In the last year, the debate on climate change in the United States has shifted from "Whether it is happening" to "What should we do about it?" In Congress, this debate has taken the form of deliberations on various "cap and trade" bills, and energy legislation. In the national security community, action has been taken to implement many of the recommendations of the CNA report:

- One of the first steps we recommended, based on our study, was that the intelligence community conduct an intelligence estimate of the national security consequences of climate change. Just this week, the National Intelligence Council has issued its first National Intelligence Assessment of the National Security Implications of Climate Change.
- Congress directed, as part of the FY08 Defense Authorization bill, that the national security implications of climate change be included the President's National Security Strategy and in DoD's National Defense Strategy.
- As part of the Senate's leading climate change legislation, cosponsored by Senator Lieberman and Senator Warner—Senator Warner cited the persuasive case made by CNA's Military Advisory Board, and their concern for the security costs and risks of climate change.
- Based on our fifth recommendation, the Defense Department's Strategic Environmental Research and Development Program has requested evaluations of the impact of sea level rise and ecological risks to military installations and their critical missions.

Mr. Chairman, the threats posed by climate change can best be addressed by the very qualities that make America a great nation: leadership, innovation for smart solutions, and global engagement.

U.S. Leadership is Essential

As I have traveled over the past year to discuss the report, there have been many occasions where members of the audience have revealed to me their sense of cautious optimism, wondering if the voices of our Military Advisory Board would finally be enough to move the U.S. government into action. While many of our allies have begun to pay serious attention to climate change, they are still waiting for the U.S., knowing that U.S. leadership is essential. While other major countries, such as China and India, should be part of the solution, they need to know that the U.S. is determined to act to create a more sustainable future. We must lead in the fight against global climate change if we are to retain our standing as a global power in the 21st century.

One of the clearest signs of leadership the U.S. could take would be to begin the transition to lower carbon energy sources and more emphasis on energy productivity and efficiency as a key element of Sustainable Energy for the 21st century. Taking action now will create opportunity for the U.S. economy, in growing green sector jobs, and in American leadership in innovation and sustainable security.

Adopt Sustainable Energy Strategies and Policies

Numerous Department of Defense studies, including a recent report of the Defense Science Board, have found that our military's combat forces would be more capable and less vulnerable by significantly reducing fuel demand. As General Mattis, who is now Commander of U.S. Joint Forces Command, stated while commanding the First Marine Division during Operation Iraqi Freedom: "Unleash us from the tether of fuel."

Transporting fuel to the front of the battlefield takes its toll in human lives. Soldiers must transport fuel to the front in vulnerable road-bound convoys. Numerous DoD studies have concluded that high fuel demand by combat forces detracts from combat capability, makes our forces more vulnerable, diverts combat assets from offense to supply line protection, and increases operating costs. Nowhere are these problems more evident than in Iraq, where millions of gallons of fuel is moved through dangerous territory everyday, requiring protection by armored combat vehicles and attack helicopters.

The human and economic cost of delivering fuel to combat forces is significant. Energy efficient technologies, energy conservation practices, and renewable energy sources can all reduce the costs of American lives on the battlefield.

In addition, the Defense Department is almost completely dependent on electricity from the national grid to power critical missions at fixed installations. The national electric grid is fragile and can be easily disrupted, as happened in the Northeast Blackout of 2003, caused by trees falling onto power lines in Ohio. It affected 50 million people in eight states and Canada, took days to restore and caused a financial loss in the U.S. estimated to be between $4 billion and $10 billion. As extreme weather events become more common, so do the threats to our national electricity supply.

One approach discussed in the CNA report to securing power to DoD installations for critical missions involves a combination of aggressively applying energy efficiency technologies to reduce the critical load and deploying renewable energy sources. By investing now in these types of technologies and improved operational processes, DoD would become an early adopter of innovative technologies that would help transform the grid, reduce our load, and expand the use of renewable energy.

REDUCE RISK NOW THROUGH CONSTRUCTIVE GLOBAL ENGAGEMENT

The risks posed by climate change present an opportunity for U.S. global leadership through constructive engagement with fragile and affected nations around the world. Climate change also creates the opportunity to advance the much needed integration of the national security, sustainable development and foreign assistance communities to harness the full potential of all elements of U.S. national power. In many dimensions of U.S. global engagement, from trade and agricultural policies, to foreign assistance, humanitarian relief, and disaster response, infusing climate resilience and sustainable approaches will benefit both the U.S. and reduce climate risks in the future.

As we know, U.S. forces are often deployed as the global "911" force. For example, the U.S. military helped deliver relief to the victims of the 2005 Indian Ocean tsunami because it is the only institution capable of rapidly delivering personnel and material anywhere in the world on relatively short notice. U.S. agencies, civilian and military, in partnership with non-governmental organizations and the private sector, can engage before disaster strikes to build capacity and resilience to reduce climate threats in the future, gain support for America's strategic interests, and build a more sustainable tomorrow.

General Zinni, former Commander of U.S. Central Command, and member of the Military Advisory Board, provides an appropriate final comment on the costs of inaction:

"We will pay for this one way or another. We will pay to reduce greenhouse gas emissions today or we will pay the price later in military terms. And that will involve human lives. There will be a human toll. There is no way out of this that does not have real costs attached to it. That has to hit home."

Thank you for the opportunity to appear before the Subcommittee.

Mr. BOUCHER. Ms. Goodman, thank you. We are going to need to pass on to other witnesses at this point. Thank you very much for your testimony. Dr. Janetos, please.

STATEMENT OF ANTHONY C. JANETOS, DIRECTOR, JOINT GLOBAL CHANGE RESEARCH INSTITUTE, PACIFIC NORTHWEST NATIONAL LABORATORY, UNIVERSITY OF MARYLAND

Mr. JANETOS. Thank you, Mr. Chairman, and thank you, members of the committee for asking me to be here to testify today. I am the director of the Joint Global Change Research Institute, a joint venture between the Pacific Northwest National Lab and the University of Maryland. What I want to focus my remarks on is this report, "The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States." This is one of 21 synthesis and assessment projects which have been undertaken by the U.S. Climate Change Science program, the purpose of which is to evaluate the scientific literature on topics of major concern.

The charge for this report was to evaluate the impact that changes and variations in climate have had and are likely to have on ecosystems and ecosystem services. Specifically, we were asked to look at agriculture, land resources, water resources, and biodiversity, and we have written in-depth chapters on each of these topics. We focused our efforts on understanding the data over the past several decades and evaluating the potential for impacts over the next several decades, while remaining mindful of impacts that will take longer to express themselves. We assessed the existing peer-reviewed scientific literature, in addition to assessing the adequacy of existing monitoring programs for documenting climate change impacts. We were not chartered to make recommendations or to advise the government on policy.

There were 37 different authors from a wide range of institutions. We have gone through peer review, public comment period, oversight by a very senior review panel, and we are confident that our review of the literature, our findings, and our judgments are sound. I have attached the executive summary of this report to this statement as part of the written record, so I will not try to summarize the 300 pages of the entire document here, but what I would like to do is point out the five overarching conclusions that we reached, and then offer some personal observations about their implications.

The first of these is that climate changes, increases in temperature, increases in the atmospheric concentration of carbon dioxide, and altered patterns of precipitation are already affecting U.S. natural resources and natural environments. We have specific examples of each of these in each of the sectors that we looked at, from the increases in pathogens and fire frequencies in the Nation's forests, especially in the West, to decreases in snowpack, and increases in early-season runoff in streams in climactically sensitive parts of the country, to sea level rise and coral-bleaching events. Not only in the U.S., but around the world, we are already beginning to see the impact of both natural variability and human-induced variability in the climate system in our natural resources.

Secondly, climate change will continue to have significant effects on these resources over the next few decades and beyond. This is a summary, not only of the current science, but really of the past decade and longer of scientific research.

Third, though it sounds trivial to say this, it is worth remembering that many other stresses and disturbances also effect these natural resources. Climate change operates in the context of many other factors that influence the current state and the expected future state of natural resources and ecosystems.

Fourth, climate change impacts and ecosystems will impact the services that these systems provide that are not traded in marketplaces, such as cleaning water or removing carbon from the atmosphere. But we do not yet possess sufficient understanding to project, quantitatively, the timing, magnitude, and consequences of the changes in services.

And lastly, the existing systems that we have for monitoring climate ecosystems, while they are useful for many purposes, are not optimized for detecting the impacts of climate change on these ecosystems.

We have moved greatly in the scientific community over the last 20 years from a very cautious examination of model results to an increasing realization that there is now substantial documentation of current impacts, and in many cases, these impacts appear to be happening more rapidly, and have greater magnitude than we might have expected to see, even as little as a decade ago.

There is a large literature on the responses of these systems and natural resources to climate variability, whether the source of that change in the climate system is natural variability or caused by human activities. There is a growing literature that not only documents the responses of ecosystems, but in addition begins to document that the climate change that they are responding to is, in fact, caused by humans. This progression is easily seen over the last several IPCC reports, and we point it out in our own report as well.

This is not to say that all of the science of climate impacts is settled—far from it. We have many areas in which improved research and better observations would enable us to continue to reduce uncertainties in our understanding and improve our capacities to make forecasts about impacts. But it does mean that we are beginning to see impacts in the natural world today, when the climate drivers are still relatively modest, compared to reasonable scenarios of the future that have already been examined by the scientific community. We are already working on additional publications to explore those research topics.

It will remain important to devote efforts to continue documentation of the state of these natural resources to research that understands how they react to changes in climate and to models that can give us reasonable expectation for the future. In the short term, in addition to constructing strategies for greenhouse gas emissions, as this committee just heard this morning from Lord Stern, it will be just as important to invest in strategies for coping and adapting to those impacts that cannot be avoided over the next several decades. This is an immediate challenge for both research and for management of natural resources, and in our authors' collective view is a critical need. It is most important in our view that such strategies be derived from the best available science. Thank you very much.

[The prepared statement of Mr. Janetos follows:]

Testimony of Dr. Anthony C. Janetos

Subcommittee on Energy and Air Quality, House of Representatives Committee on Energy and Commerce

26 June 2008

One-Page Summary of Main Points of Testimony

1. Climate changes – temperature increases, increasing CO_2 levels, and altered patterns of precipitation – are already affecting US water resources, agriculture, land resources, and biodiversity.
2. Climate change will continue to have significant effects on these resources over the next few decades and beyond.
3. Many other stresses and disturbances are also affecting these resources.
4. Climate change impacts on ecosystems will affect the services that ecosystems provide, such as cleaning water and removing carbon from the atmosphere, but we do not yet possess sufficient understanding to project the timing, magnitude, and consequences of many of these effects.
5. Existing monitoring systems, while useful for many purposes, are not optimized for detecting the impacts of climate change on ecosystems.

Testimony of Dr. Anthony C. Janetos

Subcommittee on Energy and Air Quality, House of Representatives Committee on Energy and Commerce

26 June 2008

Mr. Chairman, and members of the Committee, thank you for asking me to be here to testify today. My name is Anthony C. Janetos, and I am the Director of the Joint Global Change Research Institute, a joint venture between the Pacific Northwest National Laboratory and the University of Maryland. My oral testimony, and this written statement will focus on the report that was recently released by the Climate Change Science Program (CCSP) and US Department of Agriculture, *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*. This report is one of the 21 Synthesis and Assessment reports undertaken by the US Climate Change Science Program, the purpose of which is to synthesize the scientific literature on topics of concern to US policy makers, private sector decision makers, and the general public.

Charge and Focus of the Report

The charge for this report was to evaluate the influence that changes and variability in climate have had, and are likely to have on US ecosystems and ecosystem services. Specifically, we were asked to look at agriculture, land resources, water resources, and biodiversity, and we have written in-depth chapters on each of these topics. We focused our efforts on understanding the data for the past several decades, and evaluating the potential for impacts over the next several decades, while remaining mindful of impacts that will take longer to express themselves. We were asked by the CCSP to assess the existing peer-reviewed scientific literature, in addition to assess the adequacy of existing monitoring programs for documenting climate change impacts, and to make inferences about the state of ecosystem services. We were not chartered to make recommendations or give advice to the government for policy formulation, nor for research. We were also not chartered to investigate the potential for adaptation and coping responses, as this was the topic of a separate report from the CCSP.

Authors and Review Process

The author team that we assembled had representatives from universities, the National Laboratories, and non-governmental organizations. The coordinating lead authors were Peter Backlund, of the National Center for Atmospheric Research, myself, and David Schimel, CEO of the National Ecological Observatory Network. In addition to ourselves, 34 additional scientists contributed either to leading individual chapters or to assisting with text in their particular specialties. Our report was overseen by a FACA-chartered committee, chaired by Thomas Lovejoy, President of the H. John Heinz III Center for Science, Economics, and the Environment. In addition to our FACA committee review, we also went through a public comment period, and technical review by experts and government scientists. We responded to every review comment we received, and all of the review comments and our responses are publicly available. Following our final meeting and sign-off from the FACA oversight committee, our report went through the prescribed interagency clearance process, as have all other of the completed CCSP Synthesis and Assessment reports. We are confident that our review of the literature, our findings, and our judgments have been thoroughly and professionally reviewed, and that our conclusions are sound.

I have attached the Executive Summary of the report to this statement as part of the written record, so I will not attempt to summarize the entire document here. However, I will point out the overarching conclusions of the report, and offer some personal observations about their importance.

Overarching Conclusions of the Report

6. Climate changes – temperature increases, increasing CO_2 levels, and altered patterns of precipitation – are already affecting US water resources, agriculture, land resources, and biodiversity.
7. Climate change will continue to have significant effects on these resources over the next few decades and beyond.
8. Many other stresses and disturbances are also affecting these resources.
9. Climate change impacts on ecosystems will affect the services that ecosystems provide, such as cleaning water and removing carbon from the atmosphere, but

we do not yet possess sufficient understanding to project the timing, magnitude, and consequences of many of these effects.

10. Existing monitoring systems, while useful for many purposes, are not optimized for detecting the impacts of climate change on ecosystems.

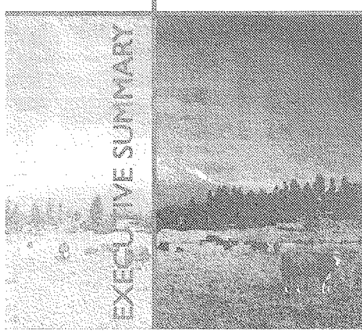
Implications of These Conclusions

There has been a profound change in the way in which the scientific community thinks and writes about the impacts of climate change on ecosystems and natural resources. For those of us who have been working on these issues for some time (in my own case, approaching 20 years), we have moved from the cautious examination of modeling results to a realization that there is now substantial documentation of current impacts. In many cases, these impacts appear to be happening more rapidly and have greater magnitude than we might have expected even as little as a decade ago.

There is a large literature on the responses of ecosystems and natural resources to climate variability, whether that variability was natural, or caused by human activities. There is now an increasing literature that not only documents the responses of ecosystems, individual animal and plant species, and natural resources to climate variability, but in addition, begins to document that human activities themselves are driving the changes in the climate system. This progression is clearly seen over the last several IPCC reports, for example, and we also point it out in our CCSP report.

This is not to say that all the science of climate impacts is settled – far from it. We point out in our report many areas in which improved scientific research and better observations would continue to reduce uncertainties in our understanding, and improve our capacity to make forecasts about impacts. But it does mean that we are beginning to see impacts in the natural world already, when the climate drivers are still relatively modest, compared to reasonable scenarios of the future that the scientific community has explored. It reminds us that while our models are imperfect and can be improved, they have nevertheless yielded important insights into the responses of ecological systems to a changing climate. The author team of our report is currently working on additional publications to explore those research topics that in our view would enhance our ability to understand and predict climate-related impacts better than we do today.

It will remain important to devote efforts to continued documentation of the state of ecosystems, to research to understand how that state reacts to changes in climate, and to models that can give us expectations for the future. However, it will be just as important to invest in strategies for coping and adaptation to those impacts that cannot be avoided as it is to construct strategies for greenhouse gas emissions. Adapting to or coping with climate change that cannot be avoided is an immediate challenge for both research and effective management of natural resources, and in our collective view is a critical need. The successful implementation of adaptation strategies for natural resources and ecosystems will need to take into account that these systems face many stresses, and that there are multiple stakeholders with legitimate interests in them. Most importantly, from our perspective, though, is that adaptation strategies must be based on the best available science.



Lead Authors: Peter Backlund, NCAR; Anthony Janetos, PNNL/Univ. Maryland; David Schimel, National Ecological Observatory Network
Contributing Authors: J. Hatfield, USDA ARS; M. Ryan, USDA Forest Service; S. Archer, Univ. Arizona; D. Lettenmaier, Univ. Washington

1 INTRODUCTION AND BACKGROUND

This report is an assessment of the effects of climate change on U.S. land resources, water resources, agriculture, and biodiversity. It is one of a series of 21 Synthesis and Assessment Products being produced under the auspices of the U.S. Climate Change Science Program (CCSP), which coordinates the climate change research activities of U.S. government agencies. The lead sponsor of this particular assessment product is the U.S. Department of Agriculture (USDA). The project was led and coordinated by the National Center for Atmospheric Research (NCAR).

This assessment is based on extensive review of the relevant scientific literature and measurements and data collected and published by U.S. government agencies. The team of authors includes experts in the fields of agriculture, biodiversity, and land and water resources – scientists and researchers from universities, national laboratories, non-government organizations, and government agencies. To generate this assessment of the effects of climate and climate change, the authors conducted an exhaustive review, analysis, and synthesis of the scientific literature, considering more than 1,000 separate publications.

Scope

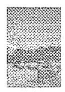
The CCSP agencies agreed on the following set of topics for this assessment. Descriptions of the major findings in each of these sectors can be found in Section 4 of this Executive Summary.

- Agriculture: (a) cropping systems, (b) pasture and grazing lands, and (c) animal management
- Land Resources: (a) forests and (b) arid lands
- Water Resources: (a) quantity, availability, and accessibility and (b) quality
- Biodiversity: (a) species diversity and (b) rare and sensitive ecosystems

The CCSP also agreed on a set of questions to guide the assessment process. Answers to these questions can be found in Section 3 of this summary:

- What factors influencing agriculture, land resources, water resources, and biodiversity in the United States are sensitive to climate and climate change?
- How could changes in climate exacerbate or ameliorate stresses on agriculture, land resources, water resources, and biodiversity? What are the indicators of these stresses?
- What current and potential observation systems could be used to monitor these indicators?
- Can observation systems detect changes in agriculture, land resources, water resources, and biodiversity that are caused by climate change, as opposed to being driven by other causes?

Our charge from the CCSP was to address the specific topics and questions from the prospectus. This had several important consequences for this report. We were asked not to make recommendations and we have adhered to this request. Our document is not a plan for scientific or agency action, but rather an assessment and analysis of current scientific understanding of the topics defined by the CCSP. In addition, we were asked not to define and examine options for adapting to climate change impacts. This topic is addressed in a separate CCSP Synthesis and Assessment Product. Our authors view adaptation as a very important issue and recognize that adaptation options will certainly affect the ultimate severity of many climate change impacts. Our findings and conclusions are relevant to informed assessment of adaptation options, but we have not attempted that task in this report.



> ... our main focus is on the recent past and the nearer-term future – the next 25 to 50 years. This period is within the planning horizon of many natural resources managers. Furthermore, the climate change that will occur during this period is relatively well understood.

Time Horizon

Many studies of climate change have focused on the next 100 years. Model projections out to 2100 have become the de facto standard, as in the assessment reports produced by the Intergovernmental Panel on Climate Change (IPCC). This report has benefited greatly from such literature, but our main focus is on the recent past and the nearer-term future – the next 25 to 50 years. This period is within the planning horizon of many natural resources managers. Furthermore, the climate change that will occur during this period is relatively well understood. Much of this change will be caused by greenhouse gas emissions that have already happened. It is thus partially independent of current or planned emissions control measures and the large scenario uncertainty that affects longer-term projections. We report some results out to 100 years to frame our assessment, but we emphasize the coming decades.

Ascribing Confidence to Findings

The authors have endeavored to use consistent terms, agreed to by the CCSP agencies, to describe their confidence in the findings and conclusions in this report, particularly when these involve projections of future conditions and accumulation of information from multiple sources. The use of these terms represents the judgment of the authors of this document; much of the underlying literature does not use such a lexicon and we have not retroactively applied this terminology to previous studies by other authors.

Climate Context

There is a robust scientific consensus that human-induced climate change is occurring. The Fourth Assessment Report (AR4) of the IPCC, the most comprehensive and up-to-date scientific assessment of this issue, states with "very high confidence" that human activities, such as fossil fuel burning and deforestation, have altered the global climate. During the 20th century, the global average surface temperature increased by about 0.6°C and global sea level increased by about 15 to 20 cm. Global precipitation over land increased about two percent during this same period. Looking ahead, human influences will continue to change Earth's climate throughout the 21st century. The IPCC AR4 projects that the global average temperature will rise another 1.1 to 5.4°C by 2100, depending on how much the atmospheric concentrations of greenhouse gases increase during this time. This temperature rise will result in continued increases in sea level and overall rainfall, changes in rainfall patterns and timing, and decline in snow cover, land ice, and sea ice extent. It is very likely that the Earth will experience a faster rate of climate change in the 21st century than seen in the last 10,000 years.

The United States warmed and became wetter overall during the 20th century, with changes varying by region. Parts of the South have cooled, while northern regions have warmed – Alaskan temperatures have increased by 2 to 4°C (more than four times the global average). Much of the eastern and southern United States now receive more precipitation than 100 years ago, while other areas, especially in the Southwest, receive less. The frequency and duration of heat waves has increased, there have been large declines in summer sea ice in the Arctic, and there is some evidence of increased frequency of heavy rainfalls. Observational and modeling results documented in the IPCC AR4 indicate that these trends are very likely to continue. Temperatures in the United States are very likely to increase by another 1°C to more than 4°C. The West and Southwest are likely to become drier, while the eastern United States is likely to experience increased rainfall. Heat waves are very likely to be hotter, longer, and more frequent, and heavy rainfall is likely to become more frequent.

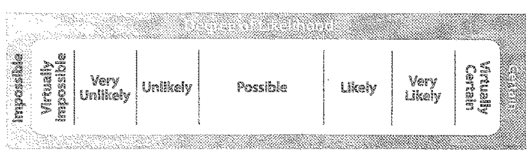


Figure 1 Language for Describing Confidence in Findings

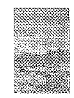
2 OVERARCHING CONCLUSIONS

Climate changes – temperature increases, increasing CO_2 levels, and altered patterns of precipitation – are already affecting U.S. water resources, agriculture, land resources, and biodiversity *(very likely).* The literature reviewed for this assessment documents many examples of changes in these resources that are the direct result of variability and changes in the climate system, even after accounting for other factors. The number and frequency of forest fires and insect outbreaks are increasing in the interior West, the Southwest, and Alaska. Precipitation, streamflow, and stream temperatures are increasing in most of the continental United States. The western United States is experiencing reduced snowpack and earlier peaks in spring runoff. The growth of many crops and weeds is being stimulated. Migration of plant and animal species is changing the composition and structure of arid, polar, aquatic, coastal, and other ecosystems.

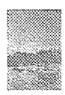
Climate change will continue to have significant effects on these resources over the next few decades and beyond *(very likely).* Warming is very likely to continue in the United States during the next 25 to 50 years, regardless of reductions in greenhouse gas emissions, due to emissions that have already occurred. U.S. ecosystems and natural resources are already being affected by climate system changes and variability. It is very likely that the magnitude and frequency of ecosystem changes will continue to increase during this period, and it is possible that they will accelerate. As temperature rises, crops will increasingly experience temperatures above the optimum for their reproductive development, and animal production of meat or dairy products will be impacted by temperature extremes. Management of Western reservoir systems is very likely to become more challenging as runoff patterns continue to change. Arid areas are very likely to experience increases erosion and fire risk. In arid ecosystems that have not coevolved with a fire cycle, the probability of loss of iconic, charismatic megaflora such as Saguaro cacti and Joshua trees will greatly increase.

Many other stresses and disturbances are also affecting these resources *(very likely).* For many of the changes documented in this assessment, there are multiple environmental drivers – land use change, nitrogen cycle changes, point and nonpoint source pollution, wildfires, invasive species – that are also changing. Atmospheric deposition of biologically available nitrogen compounds continues to be an important issue, along with persistent ozone pollution in many parts of the country. It is very likely that these additional atmospheric effects cause biological and ecological changes that interact with changes in the physical climate system. In addition, land cover and land use patterns are changing, e.g., the increasing fragmentation of U.S. forests as exurban development spreads to previously undeveloped areas, further raising fire risk and compounding the effects of summer drought, pests, and warmer winters. There are several dramatic examples of extensive spread of invasive species throughout rangeland and semiarid ecosystems in western states, and indeed throughout the United States. It is likely that the spread of these invasive species, which often change ecosystem processes, will exacerbate the risks from climate change alone. For example, in some cases invasive species increase fire risk and decrease forage quality.

Climate change impacts on ecosystems will affect the services that ecosystems provide, such as cleaning water and removing carbon from the atmosphere *(very likely)*, but we do not yet possess sufficient understanding to project the timing, magnitude, and consequences of many of these effects. One of the main reasons to assess changes in ecosystems is to understand the consequences of those changes for the delivery of services that our society values. There are many analyses of the impacts of climate change on individual species and ecosystems in the scientific literature, but there is not yet adequate integrated analysis of how climate change could affect ecosystem services. A comprehensive understanding of impacts on these services will only be possible through quantification of anticipated alterations in ecosystem function and productivity. As described by the Millennium Ecosystem Assessment, some products of ecosystems, such as food and fiber, are priced and traded in markets.



Climate changes – temperature increases, increasing CO_2 levels, and altered patterns of precipitation – are already affecting U.S. water resources, agriculture, land resources, and biodiversity.



Others, such as carbon sequestration capacity, are only beginning to be understood and traded in markets. Still others, such as the regulation of water quality and quantity and the maintenance of soil fertility, while not priced and traded, are valuable nonetheless. Although these points are recognized and accepted in the scientific literature and increasingly among decision makers, there is no analysis specifically devoted to understanding changes in ecosystem services in the United States from climate change and associated stresses. It is possible to make some generalizations from the literature on the physical changes in ecosystems, but interpreting what these changes mean for services provided by ecosystems is very challenging and can only be done for a limited number of cases. This is a significant gap in our knowledge base.

Existing monitoring systems, while useful for many purposes, are not optimized for detecting the impacts of climate change on ecosystems. There are many operational and research monitoring systems in the United States that are useful for studying the consequences of climate change on ecosystems and natural resources. These range from the resource- and species-specific monitoring systems that land-management agencies depend on to research networks, such as the Long-Term Ecological Research (LTER) sites, which the scientific community uses to understand ecosystem processes. All of the existing monitoring systems, however, have been put in place for other reasons, and none have been optimized specifically for detecting the effects and consequences of climate change. As a result, it is likely that only the largest and most visible consequences of climate change are being detected. In some cases, marginal changes and improvements to existing observing efforts, such as USDA snow and soil moisture measurement programs, could provide valuable new data detection of climate impacts. But more refined analysis and/or monitoring systems designed specifically for detecting climate change effects would provide more detailed and complete information and probably capture a range of more subtle impacts. Such systems, in turn, might lead to early-warning systems and more accurate forecasts of potential future changes. But it must be emphasized that improved observations, while needed, are not sufficient for improving understanding of ecological impacts of climate change. Ongoing, integrated and systematic analysis of existing and new observations could enable forecasting of ecological change, thus garnering greater value from observational activities, and contribute to more effective evaluation of measurement needs. This issue is addressed in greater detail in Section 3.

Existing monitoring systems, while useful for many purposes, are not optimized for detecting the impacts of climate change on ecosystems.

3 KEY QUESTIONS AND ANSWERS

This section presents a set of answers to the guiding questions posed by the CCSP agencies, derived from the longer chapters that follow this Executive Summary.

What factors influencing agriculture, land resources, water resources, and biodiversity in the United States are sensitive to climate and climate change? Climate change affects average temperatures and temperature extremes; timing and geographical patterns of precipitation; snowmelt, runoff, evaporation, and soil moisture; the frequency of disturbances, such as drought, insect and disease outbreaks, severe storms, and forest fires; atmospheric composition and air quality; and patterns of human settlement and land use change. Thus, climate change leads to myriad direct and indirect effects on U.S. ecosystems. Warming temperatures have led to effects as diverse as altered timing of bird migrations, increased evaporation, and longer growing seasons for wild and domestic plant species. Increased temperatures often lead to a complex mix of effects. Warmer summer temperatures in the western United States have led to longer forest growing seasons but have also increased summer drought stress, vulnerability to insect pests, and fire hazard. Changes to precipitation and the size of storms affect plant-available moisture, snowpack and snowmelt, streamflow, flood hazard, and water quality.

How could changes in climate exacerbate or ameliorate stresses on agriculture, land resources, water resources, and biodiversity? What are the indicators of these stresses? Ecosystems and their services (land and water resources, agriculture, biodiversity) experience a wide range of stresses, including pests and pathogens, invasive species, air pollution, extreme events, wildfires and floods. Climate change can cause or exacerbate direct stress through high temperatures, reduced water availability, and altered frequency of extreme events and severe storms. It can ameliorate stress through warmer springs and longer growing seasons, which, assuming adequate moisture, can increase agricultural and forest productivity. Climate change can also modify the frequency and severity of stresses. For example, increased minimum temperatures and warmer springs extend the range and lifetime of many pests that stress trees and crops. Higher temperatures and/or decreased precipitation increase drought stress on wild and crop plants, animals and humans. Reduced water availability can lead to increased withdrawals from rivers, reservoirs, and groundwater, with consequent effects on water quality, stream ecosystems, and human health.

What current and potential observation systems could be used to monitor these indicators? A wide range of observing systems within the United States provides information on environmental stress and ecological responses. Key systems include National Aeronautics and Space Administration (NASA) research satellites, operational satellites and ground-based observing networks from the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce, Department of Agriculture (USDA) forest and agricultural survey and inventory systems, Department of Interior/U.S. Geological Survey (USGS) stream gauge networks, Environmental Protection Agency (EPA) and state-supported water quality observing systems, the Department of Energy (DOE) Ameriflux network, and the LTER network and the proposed National Ecological Observing Network (NEON) sponsored by the National Science Foundation (NSF). However, many key biological and physical indicators are not currently monitored, are monitored haphazardly or with incomplete spatial coverage, or are monitored only in some regions. In addition, the information from these disparate networks is not well integrated. Almost all of the networks were originally instituted for specific purposes unrelated to climate change and cannot necessarily be adapted to address these new questions.

Climate change presents new challenges for operational management. Understanding climate impacts requires monitoring both many aspects of climate and a wide range of biological and physical responses. Putting climate change impacts in the context of multiple stresses and forecasting future services requires an integrated analysis. Beyond the problems of integrating the data sets, the nation has limited operational capability for integrated ecological monitoring, analyses, and forecasting. A few centers exist, aimed at specific questions and/or regions, but no coordinating agency or center has the mission to conduct integrated environmental analysis and assessment by pulling this information together.

Operational weather and climate forecasting provides an analogy. Weather-relevant observations are collected in many ways, ranging from surface observations through radiosondes to operational and research satellites. These data are used at a handful of university, federal, and private centers as the basis for analysis, understanding, and forecasting of weather through highly integrative analyses blending data and models. This operational activity requires substantial infrastructure and depends on federal, university, and private sector research for continual improvement. By contrast, no such integrative analysis of comprehensive ecological information is carried out, although the scientific understanding and societal needs have probably reached the level where an integrative and operational approach is both feasible and desirable.

Can observation systems detect changes in agriculture, land resources, water resources, and biodiversity that are caused by climate change, as opposed to being driven by other causes? In general, the current suite of observing systems is reasonably able overall to monitor ecosystem change and health in the United States, but neither the observing systems nor

Warming temperatures have led to effects as diverse as altered timing of bird migrations, increased evaporation, and longer growing seasons for wild and domestic plant species.

the current state of scientific understanding is adequate to rigorously quantify climate contributions to ecological change and separate these from other influences. Monitoring systems for measuring long-term response of **agriculture** to climate and other stresses are numerous, but integration across these systems is limited. There is no coordinated national network for monitoring changes in **land resources** associated with climate change, most disturbances, such as storms, insects, and diseases, and changes in land cover/land use. No aspect of the current hydrologic observing system was designed specifically to detect climate change or its effects on **water resources**. The monitoring systems that have been used to evaluate the relationship between changes in the physical climate system and **biological diversity** were likewise not designed with climate variability or change in mind.

Climate change is likely to lead to a northern migration of weeds.

So for the moment, there is no viable alternative to using the existing systems for identifying climate change and its impacts on U.S. agriculture, land resources, water resources, and biodiversity, even though these systems were not originally designed for this purpose. There has obviously been some considerable success so far in doing so, but there is limited confidence that the existing systems provide a true early warning system capable of identifying potential impacts in advance. The authors of this report also have very limited confidence in the ability of current observation and monitoring systems to provide the information needed to evaluate the effectiveness of actions that are taken to mitigate or adapt to climate change impacts. Furthermore, we emphasize that improvements in observations and monitoring of ecosystems, while desirable, are not sufficient by themselves for increasing our understanding of climate change impacts. Experiments that directly manipulate climate and observe impacts are critical for developing more detailed information on the interactions of climate and ecosystems, attributing impacts to climate, differentiating climate impacts from other stresses, and designing and evaluating response strategies. Much of our understanding of the direct effects of temperature, elevated CO_2, ozone, precipitation, and nitrogen deposition has come from manipulative experiments. Institutional support for such experiments is a concern.

4 SECTORAL FINDINGS

Agriculture

The broad subtopics considered in this section are cropping systems, pasture and grazing lands, and animal management. The many U.S. crops and livestock varieties (valued at about $200 billion in 2002) are grown in diverse climates, regions, and soils. No matter the region, however, weather and climate factors such as temperature, precipitation, CO_2 concentrations, and water availability directly impact the health and well-being of plants, pasture, rangeland, and livestock. For any agricultural commodity, variation in yield between years is related to growing-season weather; weather also influences insects, disease, and weeds, which in turn affect agricultural production.

- With increased CO_2 and temperature, the life cycle of grain and oilseed crops will likely progress more rapidly. But, as temperature rises, these crops will increasingly begin to experience failure, especially if climate variability increases and precipitation lessens or becomes more variable.

- The marketable yield of many horticultural crops – e.g., tomatoes, onions, fruits – is very likely to be more sensitive to climate change than grain and oilseed crops.

- Climate change is likely to lead to a northern migration of weeds. Many weeds respond more positively to increasing CO_2 than most cash crops, particularly C3 "invasive" weeds. Recent research also suggests that glyphosate, the most widely used herbicide in the United States, loses its efficacy on weeds grown at the increased CO_2 levels likely in the coming decades.

- Disease pressure on crops and domestic animals will likely increase with earlier springs and warmer winters, which will allow proliferation and higher survival rates of pathogens and parasites. Regional variation in warming and changes in rainfall will also affect spatial and temporal distribution of disease.

- Projected increases in temperature and a lengthening of the growing season will likely extend forage production into late fall and early spring, thereby decreasing need for winter season forage reserves. However, these benefits will very likely be affected by regional variations in water availability.

- Climate change-induced shifts in plant species are already under way in rangelands. Establishment of perennial herbaceous species is reducing soil water availability early in the growing season. Shifts in plant productivity and type will likely also have significant impact on livestock operations.

- Higher temperatures will very likely reduce livestock production during the summer season, but these losses will very likely be partially offset by warmer temperatures during the winter season. For ruminants, current management systems generally do not provide shelter to buffer the adverse effects of changing climate; such protection is more frequently available for non-ruminants (e.g., swine and poultry).

- Monitoring systems for measuring long-term response of agricultural lands are numerous, but integration across these systems is limited. Existing state-and-transition models could be expanded to incorporate knowledge of how agricultural lands and products respond to global change; integration of such models with existing monitoring efforts and plant developmental data bases could provide cost-effective strategies that both enhance knowledge of regional climate change impacts and offer ecosystem management options. In addition, at present, there are no easy and reliable means to accurately ascertain the mineral and carbon state of agricultural lands, particularly over large areas; a fairly low-cost method of monitoring biogeochemical response to global change would be to sample ecologically important target species in different ecosystems.

Land Resources

The broad subtopics considered in this section are forest lands and arid lands. Climate strongly influences forest productivity, species composition, and the frequency and magnitude of disturbances that impact forests. The effect of climate change on disturbances such as forest fire, insect outbreaks, storms, and severe drought will command public attention and place increasing demands on management resources. Disturbance and land use will control the response of arid lands to climate change. Many plants and animals in arid ecosystems are near their physiological limits for tolerating temperature and water stress and even slight changes in stress will have significant consequences. In the near term, fire effects will trump climate effects on ecosystem structure and function.

- Climate change has very likely increased the size and number of forest fires, insect outbreaks, and tree mortality in the interior West, the Southwest, and Alaska, and will continue to do so.

- Rising CO_2 will very likely increase photosynthesis for forests, but this increase will likely only enhance wood production in young forests on fertile soils.

- Nitrogen deposition and warmer temperatures have very likely increased forest growth where adequate water is available and will continue to do so in the near future.

- The combined effects of rising temperatures and CO_2, nitrogen deposition, ozone, and forest disturbance on soil processes and soil carbon storage remains unclear.

- Higher temperatures, increased drought, and more intense thunderstorms will very likely increase erosion and promote invasion of exotic grass species in arid lands.

- Climate change in arid lands will create physical conditions conducive to wildfire, and the proliferation of exotic grasses will provide fuel, thus causing fire frequencies to increase in a self-reinforcing fashion.

Climate change has very likely increased the size and number of forest fires, insect outbreaks, and tree mortality in the interior West, the Southwest, and Alaska, and will continue to do so.

Stream temperatures are likely to increase as the climate warms, and are very likely to have both direct and indirect effects on aquatic ecosystems.

- In arid regions where ecosystems have not coevolved with a fire cycle, the probability of loss of iconic, charismatic megaflora such as saguaro cacti and Joshua trees is very likely.

- Arid lands very likely do not have a large capacity to absorb CO_2 from the atmosphere and will likely lose carbon as climate-induced disturbance increases.

- River and riparian ecosystems in arid lands will very likely be negatively impacted by decreased streamflow, increased water removal, and greater competition from non-native species.

- Changes in temperature and precipitation will very likely decrease the cover of vegetation that protects the ground surface from wind and water erosion.

- Current observing systems do not easily lend themselves to monitoring change associated with disturbance and alteration of land cover and land use, and distinguishing such changes from those driven by climate change. Adequately distinguishing climate change influences is aided by the collection of data at certain spatial and temporal resolutions, as well as supporting ground truth measurements.

Water Resources

The broad subtopics considered in this section are water quantity and water quality. Plants, animals, natural and managed ecosystems, and human settlements are susceptible to variations in the storage, fluxes, and quality of water, all of which are sensitive to climate change. The effects of climate on the nation's water storage capabilities and hydrologic functions will have significant implications for water management and planning as variability in natural processes increases. Although U.S. water management practices are generally quite advanced, particularly in the West, the reliance on past conditions as the foundation for current and future planning and practice will no longer be tenable as climate change and variability increasingly create conditions well outside of historical parameters and erode predictability.

- Most of the United States experienced increases in precipitation and streamflow and decreases in drought during the second half of the 20th century. It is likely that these trends are due to a combination of decadal-scale variability and long-term change.

- Consistent with streamflow and precipitation observations, most of the continental United States experienced reductions in drought severity and duration over the 20th century. However, there is some indication of increased drought severity and duration in the western and southwestern United States.

- There is a trend toward reduced mountain snowpack and earlier spring snowmelt runoff peaks across much of the western United States. This trend is very likely attributable at least in part to long-term warming, although some part may have been played by decadal-scale variability, including a shift in the phase of the Pacific Decadal Oscillation in the late 1970s. Where earlier snowmelt peaks and reduced summer and fall low flows have already been detected, continuing shifts in this direction are very likely and may have substantial impacts on the performance of reservoir systems.

- Water quality is sensitive to both increased water temperatures and changes in precipitation. However, most water quality changes observed so far across the continental United States are likely attributable to causes other than climate change.

- Stream temperatures are likely to increase as the climate warms, and are very likely to have both direct and indirect effects on aquatic ecosystems. Changes in temperature will be most evident during low flow periods, when they are of greatest concern. Stream temperature increases have already begun to be detected across some of the United States, although a comprehensive analysis similar to those reviewed for streamflow trends has yet to be conducted.

- A suite of climate simulations conducted for the IPCC AR4 show that the United States may experience increased runoff in eastern regions, gradually transitioning to little change in the Missouri and lower Mississippi, to substantial decreases in annual runoff in the interior of the west (Colorado and Great Basin).

- Trends toward increased water use efficiency are likely to continue in the coming decades. Pressures for reallocation of water will be greatest in areas of highest population growth, such as the Southwest. Declining per capita (and, for some cases, total) water consumption will help mitigate the impacts of climate change on water resources.

- Essentially no aspect of the current hydrologic observing system was designed specifically to detect climate change or its effects on water resources. Recent efforts have the potential to make improvements, although many systems remain technologically obsolete, incompatible, and/or have significant data collection gaps in their operational and maintenance structures. As a result, many of the data are fragmented, poorly integrated, and unable to meet the predictive challenges of a rapidly changing climate.

Biodiversity

The broad subtopics considered in this section are species diversity and rare and sensitive ecosystems. Biodiversity, the variation of life at the genetic, species, and ecosystem levels of biological organization, is the fundamental building block of the services that ecosystems deliver to human societies. It is intrinsically important both because of its contribution to the functioning of ecosystems, and because it is difficult or impossible to recover or replace, once it is eroded. Climate change is affecting U.S. biodiversity and ecosystems, including changes in growing season, phenology, primary production, and species distributions and diversity. It is very likely that climate change will increase in importance as a driver for changes in biodiversity over the next several decades, although for most ecosystems it is not currently the largest driver of change.

- There has been a significant lengthening of the growing season and increase in net primary productivity (NPP) in the higher latitudes of North America. Over the last 19 years, global satellite data indicate an earlier onset of spring across the temperate latitudes by 10 to 14 days.

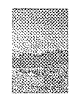
- In an analysis of 866 peer-reviewed papers exploring the ecological consequences of climate change, nearly 60 percent of the 1598 species studied exhibited shifts in their distributions and/or phenologies over the 20- and 140-year time frame. Analyses of field-based phenological responses have reported shifts as great as 5.1 days per decade, with an average of 2.3 days per decade across all species.

- Subtropical and tropical corals in shallow waters have already suffered major bleaching events that are clearly driven by increases in sea surface temperatures. Increases in ocean acidity, which are a direct consequence of increases in atmospheric carbon dioxide, are calculated to have the potential for serious negative consequences for corals.

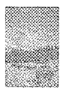
- The rapid rates of warming in the Arctic observed in recent decades, and projected for at least the next century, are dramatically reducing the snow and ice covers that provide denning and foraging habitat for polar bears.

- There are other possible, and even probable, impacts and changes in biodiversity (e.g., disruption of the relationships between pollinators, such as bees, and flowering plants), for which we do not yet have a substantial observational database. However, we cannot conclude that the lack of complete observations is evidence that changes are not occurring.

- It is difficult to pinpoint changes in ecosystem services that are specifically related to changes in biological diversity in the United States. A specific assessment of changes in ecosystem services for the United States as a consequence of changes in climate or other drivers of change has not been done.



- The monitoring systems that have been used to evaluate the relationship between changes in the physical climate system and biological diversity have three components: species-specific or ecosystem-specific monitoring systems, research activities specifically designed to create time-series of population data and associated climatic and other environmental data, and spatially extensive observations derived from remotely sensed data. However, in very few cases were these monitoring systems established with climate variability and climate change in mind, so the information that can be derived from them specifically for climate-change-related studies is somewhat limited. It is also not clear that existing networks can be maintained for long enough to enable careful time-series studies to be conducted.



It is also not clear that existing networks can be maintained for long enough to enable careful time-series studies to be conducted.

Ms. BALDWIN [presiding]. Mr. Lyons?

STATEMENT OF JIM LYONS, VICE PRESIDENT, POLICY AND COMMUNICATIONS, OXFAM AMERICA

Mr. LYONS. Thank you very much, Madam Chairman. I am Jim Lyons. I am Vice President for Policy and Communications for Oxfam America, and we certainly appreciate the opportunity to appear before the subcommittee today.

We have come to see climate change as one of the greatest challenges in our efforts in the 21st Century to promote development and to reduce global poverty, our overriding mission. In fact, we fear that climate change could be the catalyst for the greatest humanitarian crisis this world has ever known. Science indicates poor and vulnerable communities around the world will increasingly bear the brunt of the consequences of climate change, threatening the lives of millions of people and undermining global stability and security. In fact, people living in developing countries are 20 times more likely to be affected by climate-related disasters compared to those living in the industrialized world. And the number of people affected by climate-related disasters in developing countries has increased exponentially in the just the past four decades.

Estimates of climate change's contribution to worsening conditions are in fact very disturbing. By 2020, it is projected that up to 250 million people across Africa could face severe water shortages, and by midcentury, more than a billion people will face water shortages and hunger, including 600 million in Africa alone. Since the 1960, in fact, there has been a fourfold increase in the occurrence of drought in Sub-Saharan Africa.

Now, ultimately the climate challenge we face is twofold. This has been discussed today. The first is dealing with greenhouse emissions, so-called mitigation issues, but equally important, we believe, is to deal with the already realized and now-being-recognized consequences of climate change and those yet to come, so-called adaptation strategies. Climate change has been illustrated here by others and will have ramifications throughout the entire economic, political, and social fabric of developing countries in ways that will hardly be limited to what we normally think of as environmental damage.

Agriculture is clearly the economic sector that is most at risk as a result of climate change, and the sector in which the consequences of a global warming will affect the lives of the greatest number of people. It is important to note that more than 75 percent of people in developing countries still depend on agriculture as the main component of their livelihoods. Some countries' yields from rain-fed crops could be halved by 2020 due to climate impacts, and according to recent findings by Stanford University researchers, parts of southern Africa and south Asia stand to lose substantial portions of their staple crops as a result of climate impacts.

As one example of the ramifications of climate change, the World Food Program estimates that of Ethiopia's 80 million citizens, 3.4 million will need emergency food relief from July to September this year due to an extended drought that has hit the region. This is in addition to the 8 million currently receiving assistance.

The UN estimates that the incidents of malaria worldwide could increase by more than 17 millions cases annually, another ramification of climate change, the public health implications. And this has been illustrated by Sherri and by other evidence presented by security experts. There are broad ramifications for stability and security associated with climate change. Josette Sheeran, Executive Director of the World Food Program, recently warned that food-related riots in more than 30 countries were stark reminders that food insecurity threatens not only the hungry, but peace and stability itself.

In the United States, low-income and other vulnerable populations will also be disproportionately affected by climate's impacts. The U.S. Climate Change Science Program has noted that many of the expected health effects are likely to fall disproportionately on the poor, the elderly, the disabled, and the uninsured. And this has already been mentioned. We have seen dramatically the impacts of the effects of climate change as a result of the effects felt in the southeast associated with Hurricane Katrina.

Now, if moral and ethical arguments for dealing with climate crisis are not enough to afford clearly the economic imperative we have discussed at length this morning, one, even at current levels of global warming, the World Bank has estimated that the cost of protecting new investments in developing countries from climate impacts ranges from $10 to $40 billion. And last year, the UN Human Development Report estimated the need for dealing with consequences of climate change through new adaptation strategies could exceed $86 billion per year from the year 2015 and beyond.

It is vital to immediately invest in efforts to help adapt to climate change and to reduce disaster risks and improve likelihoods for improved production from agriculture and to support other sectors, really essential to avoid devastating costs that we will realize later.

We think there are opportunities associated with developing these strategies that have been discussed to some degree here, but need to be reemphasized. Working with vulnerable communities and building their resilience to the consequences of climate change can also provide a means to encourage these same communities to become more economically, socially, and politically resilient. For example, reliable access to essential service such as sanitation and clean water can help build the capacity of communities to develop themselves.

Ms. BALDWIN. Mr. Lyons, I just want to note you are approximately a minute over your time.

Mr. LYONS. And I will be 30 seconds in wrapping up. How is that?

Ms. BALDWIN. Thank you, sir.

Mr. LYONS. We think there are opportunities for investment that go beyond simply those that have been recognized in the past, such as the development of clean-energy technologies. There are investments in water-purifications systems, in climate-risk insurance, a project that we are working on currently with some of the world's largest insurers, and in building a new energy future, not just for those developing countries that we talk about often, and that is

China and India, but also for other developing community so they can get on low-carbon pathways as they enhance development.

Let me simply close by saying that I think the two lessons that come from all of this is, as the saying goes, the first way to get out of a hole is to stop digging. We clearly need to develop a strategy to address CO_2 emissions and to curb their effects, and secondly, we have to recognize the impacts of climate change, particularly for those in vulnerable communities, and particularly in the developing word, not simply as a matter of moral and ethical importance, and not simply because of the environmental consequences, but most importantly because of the social, economic, and global security ramifications if we fail to act. Thank you.

[The prepared statement of Mr. Lyons follows:]

Oxfam America

Testimony of
James R. Lyons
Vice President for Policy and Communications
Oxfam America

Before the
Subcommittee on Energy and Air Quality
Committee on Energy and Commerce
U.S. House of Representatives
On
"Climate Change: Costs of Inaction"

June 26, 2008

Introduction

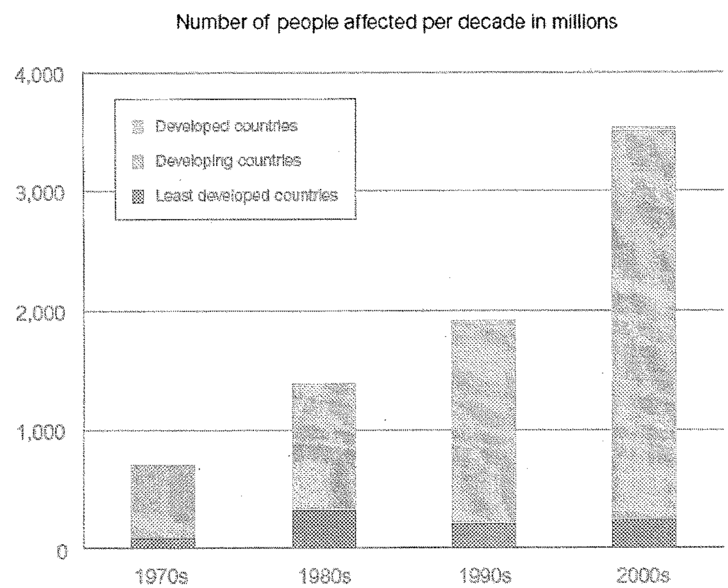
Good morning Mr. Chairman and Members of the Subcommittee.

I am Jim Lyons, Vice President for Policy and Communications for Oxfam America. Oxfam is an international development and humanitarian organization. Oxfam works with communities and partner organizations in more than 120 countries to create lasting solutions to poverty, hunger, and injustice.

We have come to see climate change as one of the greatest challenges to our efforts in the 21st century to promote development and reduce global poverty. In our operations spanning Africa, Latin America, East Asia and the United States itself, our staff and partners are already responding to the serious impacts of climate change, from increasingly severe weather events to water scarcity. Moreover, as the science indicates, poor and vulnerable communities around the world will increasingly bear the brunt of the consequences of global warming, threatening the lives of millions of people and undermining global stability and security.

The reality we face is dire for the world's poor who stand on the front lines of the global climate crisis. People living in developing countries are 20 times more likely to be affected by climate-related disasters compared to those living in the industrialized world, and nearly two billion people in developing countries were affected by climate-related disasters in the 1990s alone. As demonstrated in the following chart, the number of people affected by climate-related disasters in developing countries has increased exponentially during the past four decades.

Figure 1. Number of people affected by climate change (in millions)



Source: World Bank

The estimates of climate change's contribution to worsening conditions are disturbing. By 2020, up to 250 million people across Africa could face increasingly severe water shortages, according to the Intergovernmental Panel on Climate Change (IPCC). By mid-century, more than a billion people will face water shortages and hunger, including 600 million in Africa alone. Weather extremes, food and water scarcity, and climate-related public health threats are projected to displace between 150 million and one billion people as climate change unfolds. Even in the United States, serious public health effects could be experienced among vulnerable low-income and elderly populations. According to the recent *Scientific Assessment of the Effect of Climate Change in the US*, "climate change is very likely to accentuate the disparities already evident in the American health care system".

Our already strained capacity to respond to natural disasters and health crises around the world is being stretched even further by the increasing harm caused by climate change impacts. Yet perhaps the most significant consequence of climate change will be felt as developing countries struggle to maintain food security in the face of declining agricultural productivity and the loss of crops to weather-related disasters. The very lifeline of the world's poorest countries, where communities depend on agriculture for their very existence, is being frayed to the breaking point.

Moreover, the consequences of climate change reach significantly beyond direct impacts. Global stability and security will be undermined by increasing migration and refugee crises, by conflicts over ever-scarcer natural resources, and by economic destabilization as poverty and food insecurity grow. Our national interest will not be well-served by a failure to tackle the powerful ripple effects that climate change will cause in some of the most politically sensitive parts of the world.

Ultimately, the climate change challenge we face is two-fold. First, we must acknowledge the enormous costs that a failure to reduce greenhouse gas emissions will impose on us in the future, and we must therefore act to reduce our emissions substantially. Yet even with significant cuts in greenhouse gas emissions, we must also recognize the costs that would come from a failure to immediately address the climate change impacts being felt now. If we do not assist vulnerable communities to build resilience and adapt to climate impacts, the costs we face will be measured not only in dollars but also in lives lost.

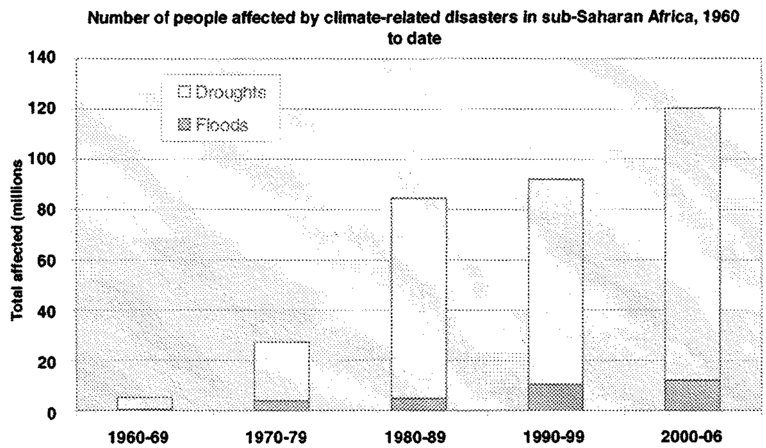
The US can re-emerge as a global leader on both of these fronts by implementing a greenhouse gas emissions reduction program that delivers dramatic, long-term emissions reductions on the order of 80% from 1990 levels by 2050, and by committing additional and substantial financing to build climate-resiliency in vulnerable communities around the world.

Impacts on vulnerable communities in developing countries

The threats that climate change poses to global poverty reduction and development are both broad and deep. Climate change will have ramifications throughout the entire economic, political, and social fabric of developing countries in ways that will hardly be limited to the arena we usually think of as "environmental." And it will affect those countries in profound ways that will alter development pathways and place substantial obstacles in the way of meeting critical poverty reduction objectives.

By 2020, between 75 million and 250 million people will be exposed to increased water stress due to reduced precipitation. Those most at risk are concentrated in the Mediterranean basin, southern Africa, portions of South America, and the western United States. These are arid and semi-arid regions that are also more likely to suffer droughts over the same time period. Figure 2 demonstrates the increasing occurrence of drought in sub-Saharan Africa since the 1960s, an almost 25 fold increase in little more than four decades.

Figure 2. Number of people affected by flood and drought in sub-Saharan Africa



Source: EM-DAT: The OF DA/CRED International Disaster Database

Meanwhile, severe weather events and resulting disasters are becoming increasingly common.

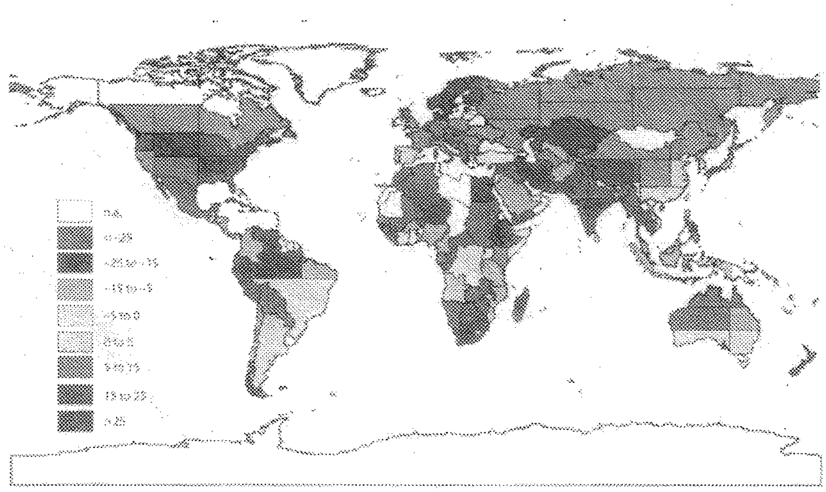
- As of August last year, some 248 million people were affected in 2007 by flooding in 11 Asian countries. Extreme floods are common in South Asia, but climate change models predict even heavier monsoon rainfall—and intense rain in unlikely places.

- Between July 2007 and October 2007, Africa's worst floods in three decades hit 23 countries from Senegal to Somalia. Nearly two million people were affected. Africa's climates are highly variable, but more climatic extremes—especially "extremely wet events"—are in line with climate change predictions.

Agriculture is the economic sector most at risk to climate impacts – and the sector in which the consequences of global warming will affect the lives of the greatest number of people. More than 75 percent of people in developing countries depend on agriculture as the main component of their livelihoods. Some countries' yields from rain-fed crops could be halved by 2020 due to climate impacts. According to recent findings by Stanford University researchers, parts of southern Africa and South Asia stand to lose substantial portions of their staple crops such as corn and rice.

A recent report by William Cline of the Center for Global Development and the Institute for International Economics provides a country-by-country analysis of reduced agricultural yields. The results show that developing countries stand to lose the most from global temerature rise (see Figure 3) and that "the composition of agricultural effects is likely to be seriously unfavorable to developing countries, with the most severe losses occuring in Africa, Latin America, and India."

Figure 3. Impact of climate change on agricultural productivity (without carbon fertilization)



Source: Cline 2007

The recent rapid increase in world food prices illustrates the human consequences of food scarcity that will be exacerbated by climate change – and may already be related to climate impacts in some cases. While a specific weather event can not be directly tied to climate change, the following are some examples of the agricultural trends that are predicted to occur in coming years due to climate change:

- The Word Food Program estimates that, of Ethiopia's 80 million citizens, 3.4 million will need emergency food relief from July to September this year due to an extended drought that has hit the region hard. This is in addition to the 8 million currently receiving assistance. UNICEF has said that the country's food shortage this year is the most severe since 2003, when droughts forced 13.2 million people to seek emergency food aid.

- A small community in the northeastern corner of South Africa, Hluhluwe, is similarly struggling to contend with eight years of drought, high unemployment, and rising poverty coupled with some of the highest HIV rates in the country. Without locally-grown vital fruits, vegetables and grains, people are unable to get the nutritious foods they need to stay healthy. In a community deeply affected by HIV and AIDS, this can have devastating consequences.

While many agricultural communities face growing water scarcity, others are also facing increased floods or sea incursions that damage valuable crops and exacerbate food shortages. Such experiences are similar to the struggles faced by farmers in the

Midwest as corn and soybean growers attempt to bounce back from devastating floods that will leave their fields waterlogged for some time to come. For example:

- The Cham people in Cambodia have previously benefited from seasonal flooding on the Mekong river floodplains providing just enough water for rice cultivation. However, in recent years they have experienced unpredictable floods, and research conducted by the Cambodian Ministry of Environment has shown that agricultural productivity in the country has decreased during the past five years because of the increased flooding, coupled with drought and sea water intrusions. The results have caused many families to leave in search of other livelihoods.

- In areas of Bangladesh monsoon flooding used to be predictable, occurring only in July or August. But now the rains are continuing through October. Increased rainfall combined with rising sea levels and overflowing rivers from melting glaciers are flooding low-lying areas at unprecedented rates, preventing communities from planting their crops. Floating vegetable gardens, raised homesteads, and flood warning systems are helping people adapt to these inhospitable conditions.

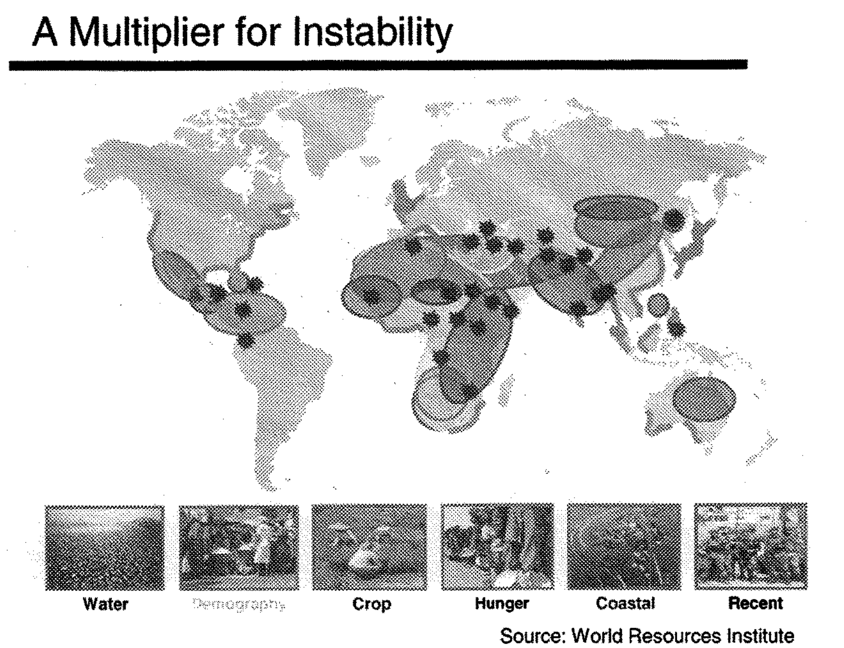
Climate change impacts will have serious implications for public health globally. As highlighted by the work of the Intergovernmental Panel on Climate Change, an expansion in the geographic areas impacted by tropical diseases like malaria and cholera is likely to occur. Warming temperatures are expanding the habitat for disease vectors such as mosquitoes and other insects, causing the spread of insect-borne diseases to more northern latitudes as well as to communities living at higher elevations. For example, the UN Framework Convention on Climate Change estimates that the incidence of malaria worldwide would increase by more than 17 million cases annually if concentrations of greenhouse gases reach 550 ppm (corresponding to a likely temperature increase of more than 3.6° F (2° C)).

Climate-related impacts will also have broad ramifications for stability and security in some of the most politically volatile regions in the world. In a recent report from the Center for Naval Analysis (CNA), a number of retired US admirals and generals refer to climate change as a "threat multiplier," presenting significant national security challenges for the United States.

Josette Sheeran, executive director of the World Food Program recently warned that food-related riots in more than 30 countries were "stark reminders that food insecurity threatens not only the hungry but peace and stability itself". This week, US intelligence agencies will present a report to Congress, "The National Security Implications of Global Climate Change Through 2030," which is expected to reach many of the same conclusions concerning the security threat posed by climates change.

As UN Secretary General Ban Ki Moon recently noted, the increased scarcity of natural resources has contributed to conflicts in areas such as Darfur. The recent conflict there coincides with a 40% decline in precipitation in Sudan, which has been linked by scientists to global temperature change and changes in rainfall patterns tied to warming in the Indian Ocean. Such examples provide us with a glimpse at what is to come in the developing world if we do not reduce the degree of warming and build resilience to the consequences of climate change.

Figure 4. A Multiplier for Instability



While the US has a strong interest in climate impacts on vulnerable communities around the world, low-income and other vulnerable populations in the US will also be disproportionately affected by predicted climate impacts. For instance, according to the recent finding of the federal U.S. Climate Change Science Program, "[m]any of the expected health effects are likely to fall disproportionately on the poor, the elderly, the disabled, and the uninsured."

In addition, Hurricane Katrina tragically illustrated the ways in which climate-related disasters can disproportionately affect the most vulnerable, imposing enormous human and economic tolls. In the future, other climate events such as floods and periods of extreme heat can be expected to have significant effects on low-income communities and other at-risk populations.

The Costs of Inaction

The costs of failing to act to address both the already realized effects of global warming and the need to dramatically reduce carbon emissions to limit the future effects of climate change are substantial and rapidly growing. The IPCC report notes that an increase in global average temperatures beyond 3.6° F (2° C) from pre-industrial levels will likely generate the most dangerous shocks to the world's water resources, food production, sea levels, and ecosystems. As Sir Nicholas Stern has indicated, if we fail to stay below the 2° C threshold and instead experience warming as high as 5-6° C (9-10.8°F), then we are likely to experience costs in excess of 10% of GDP in developing countries—countries where the vast majority of the population already lives in poverty.

If the moral and ethical arguments for dealing with the climate crisis are not yet evident, the economic imperative to reduce emissions is extremely clear. Even at current levels of global warming, the World Bank has estimated that the cost of protecting new investments in developing countries from climate impacts ranges from $10-40 billion annually. However, this estimate does not include the costs of protecting already existing investments from climate impacts, nor does it address community-level needs for climate adaptation (such as reinforcing housing stock).

An Oxfam analysis of the costs of adapting to climate impacts in developing countries has found that the needs are at least $50 billion annually, and potentially higher, when the protection of existing investments and community-level adaptation needs are incorporated.

Similarly, in their most recent Human Development Report, the United Nations Development Program (UNDP) estimates that the adaptation needs of developing countries will total $86 billion per year from 2015 onward. This estimate is based on the costs of integrating climate-resiliency into development activities (such as with irrigation systems and preventive health programs), strengthening infrastructure such as schools and roads, and adding to disaster preparedness and response capacity.

These costs will climb much higher if global temperatures increase beyond the 3.6° F (2° C) threshold. Reducing greenhouse gas emissions as quickly as possible is therefore necessary to avoid annual costs in developing countries that could easily climb into the hundreds of billions of dollars each year.

Meanwhile, it is vital to invest immediately in efforts to adapt and build resilience to climate impacts. Acting today to reduce disaster risks and improve livelihoods in agriculture and other sectors is essential in order to avoid even greater costs later. For instance, providing improved irrigation and water retention systems will help reduce future food aid costs in times of scarcity or famine. Similarly, protecting infrastructure or putting in place natural sea buffers such as mangrove forests will help reduce future disaster assistance costs.

One of the recommendations of the CNA report on climate change and national security is for the US "to assist nations at risk build the capacity and resiliency to better cope with the effects of climate change. Doing so now can help avert humanitarian disasters later."

The financial benefits from taking preventive action have been demonstrated widely. According to an analysis by the U.S. Geological Survey and the World Bank, an investment of $40 billion to reduce disaster risk is capable of preventing disaster losses of $280 billion. A study conducted by the British international development agency finds that every US$1 invested in pre-disaster risk management activities in developing countries can prevent US$7 in losses.

In China, US$3 billion spent on flood defenses in the four decades up to 2000 is estimated to have averted losses of US$12 billion. Evidence from a mangrove-planting project designed to protect coastal populations from storm surges in Viet Nam estimated economic benefits that were 52 times higher than costs. In Brazil, a flood reconstruction and prevention project designed to break the cycle of periodic flooding in 2005 has resulted in a return on investment of greater than 50% by reducing residential property damages.

Bangladesh provides a particularly compelling example of the benefits of prudent planning and risk reduction. In 1970, up to 500,000 people perished in the Bhola cyclone in Bangladesh, and in 1991 another 138,000 people were killed in the Chittagong cyclone. Bangladesh has since instituted a national cyclone preparedness program that includes shelters, early warning systems and community-based preparedness measures. Last year when Cyclone Sidr struck, a network of some 34,000 volunteers were mobilized to effectively communicate risks to millions of people – even where many had limited or no access to TV and radio – to encourage evacuation to a network of cyclone shelters. As a result, while 3,300 people perished, far more lives were saved compared to the earlier cyclones.

By contrast, when Cyclone Nargis hit the Burma (Myanmar) delta region in May, there was broad failure by the government to alert residents and provide protection. As a result, UN agencies report that more than 100,000 perished in the cyclone, and one estimate of the death roll from the Red Cross reaches as high as 127,000.

Opportunities Presented by the Climate Challenge

The linkages between climate change and the many dimensions of global development present both challenges and opportunities. Working with vulnerable communities in building their resilience to the consequences of climate change can also provide a means to encourage these same communities to become more economically, socially and politically resilient in the broadest sense. For instance, reliable access to essential services such as sanitation and clean water can help build the capacity of communities to respond to unpredictable climate events such as floods and drought but also can serve as a foundation for economic growth and development.

Often, building resilience means enhancing existing development approaches, such as improving agricultural techniques or water supply systems. At other times, however, the challenges will be new and different. For instance, some communities will have to adapt to rapidly melting mountain glaciers—creating excessive runoff and the potential for unprecedented floods now while leading to scarcer water supplies in future years once the glaciers are gone. These communities could benefit from the creation of reservoirs and water impoundments to capture and store water resources that will become increasingly scarce in the future. Alternatively, these communities may have to create flood warning systems to deal with higher water flows and may have to change agricultural practices and the crops they grow to deal with water abundance in the short term and scarcity sometime in the future.

Oxfam is exploring a variety of resilience-building approaches that promote economic development and poverty reduction thus improving climate-change resilience. Some examples include:

- *Saving for Change* (SfC) is an innovative and cost effective microfinance program targeted to the rural poor that acts as a trainer and facilitator so that groups learn to manage their own saving and lending activities. Oxfam is currently working with partners in Cambodia where small-scale farmers are implementing an agricultural technique called System of Rice Intensification (SRI). SRI has been developed to revive traditional agricultural techniques for rice farming that may prove less water intensive and more productive than modern day agricultural approaches.

- In the region of Arequipa, Peru, our partner Asociacion Proyeccion (AP) is working with communities who are affected by numerous climate changes. Several initiatives include installing radio networks to ensure that remote communities are informed of any severe weather patterns. AP has gathered local/traditional knowledge about how to predict weather patterns and what steps to take when severe storms occur. Two interesting activities have been the planting of barley in the communities to provide food for animals in the event of a frost that kills the grasses; this is then stored in underground areas to ensure that it is available year round. Finally a new system of gravity fed irrigation has been installed to ensure that the pastures are properly watered.

Meanwhile, for many companies, there are critical overlaps between climate impacts that will affect their supply chains and impacts on local communities. For example, water scarcity can affect the production of cotton for the apparel industry so that finding ways to protect shared water resources can be enormously beneficial both to those companies and to communities. Meanwhile, adaptation efforts in developing countries can provide enhanced market opportunities for developers of new technologies —such as water purification systems that don't require the use of electricity.

Responding to climate change impacts on poor communities may also present new business opportunities and spur economic development in some of the poorest regions of the world. Recent interest in "climate-risk" insurance products by the insurance industry offers one indication that global financial institutions understand the costs and benefits of emissions reduction and building climate resilience aimed at hedging future climate risks.

In Ethiopia, where 85% of the population is dependent on rain-fed agriculture, Oxfam is working with the microinsurance industry and small-scale farmers to establish an agricultural risk management program. As rainfall patterns have become more unpredictable, the poor typically cope with economic crisis through self-insurance (e.g. savings, debt, and asset liquidation), income diversification, and informal insurance arrangements. For reasons well documented in the microinsurance literature, these risk-hedging strategies all too often fail. Exacerbating the problem, particularly in Ethiopia, is farmers' own reluctance to experiment with higher risk, but higher yielding technologies like drought resistant seeds, even when affordable credit is available.

The development of new, clean energy technologies to support climate adaptation and resilience in developing countries can also provide business opportunities. Energy poverty, or the absence of access to reliable energy services, affects approximately one-third of the world's population, with 80% of those in South Asia and Sub-Saharan Africa. For example, Tanzania and Ethiopia have electricity access rates of 10% and 13% respectively, with access heavily skewed towards urban centers. The alternative energy sources that can benefit these countries are part of a rapidly growing sector (by 2016, for example, the global photovoltaic solar cell industry is projected to be worth $69.3 billion and wind power worth $60.8 billion, each generating new jobs and creating new markets for investment and trading). Building a new renewable energy future in vulnerable countries can provide the developing world with the infrastructure needed for some critically needed adaptation strategies (e.g, electricity for pumps to provide ground water for irrigation), while also helping developing nations grow along a low-carbon pathway.

Conclusion

As noted by Jim Hansen yesterday on the 20th anniversary of his first appearance before a congressional committee to sound the alarm about climate change, "We have reached the tipping level for several important effects [of climate change]. That is why we must go back in CO_2 amounts to at least 350 ppm and possibly lower."[1] For this reason, we must deliver steep reductions in US greenhouse gas emissions and invest in innovative strategies to deal with the consequences of global warming that are already evident and are certain to grow.

As the saying goes, the best way to get out of a hole is to stop digging. As Dr. Hansen, the IPCC, and many other leading experts and scientists have warned, we need to stop contributing to our own demise by substantially reducing our greenhouse gas emissions.

At the same time, we must invest in measures to help adapt to climate change and build greater resiliency for populations and communities most vulnerable to its consequences. This is particularly true in the developing world where those who are most vulnerable reside. Again, this is not simply a matter of moral and ethical importance, but one with important social, economic and global security consequences. In brief, the imperative to provide support for climate adaptation is not simply an environmental concern, but a matter of global importance on many fronts.

Mr. Chairman, we applaud your interest in climate change and the Committee's efforts to develop the body of evidence needed to guide sound decisions on how to deal with global warming and its consequences. While we are late to the table as a nation, it is still not too late to act and to demonstrate our resolve to lead in addressing what we believe to be the greatest humanitarian challenge of this century.

Thank you for the opportunity to appear before you today. I am glad to answer any questions that you may have.

[1] Remarks of Dr. James Hansen before the National Press Club on the 20th Anniversay of his testimony on climate change before the Senate Energy and Natural Resources Committee. June 23, 2008.

June 26, 2008

Summary Testimony of
James R. Lyons
Vice President for Policy and Communications
Oxfam America

As an international development and humanitarian organization, Oxfam sees climate change as one of the greatest challenges to our efforts to promote development and reduce global poverty. Poor and vulnerable communities around the world will increasingly bear the brunt of the consequences of global warming, from water scarcity to severe weather events to increased disease, threatening the lives of millions of people and undermining global stability and security.

The US must acknowledge the enormous costs that a failure to reduce greenhouse gas emissions will impose on us in the future, and we must therefore act to reduce our emissions substantially. Yet even with significant cuts in greenhouse gas emissions, we must also recognize the costs that would come from a failure to immediately address the climate change impacts being felt today. If we do not assist vulnerable communities to build resilience and adapt to climate impacts, the costs we face will be measured not only in dollars but also in lives lost.

Impacts on Vulnerable Communities in Developing Countries
The threats that climate change poses to global poverty reduction and development are both broad and deep. By 2020, up to 250 million people across Africa could face more severe water shortages. By mid-century, more than a billion people will face water shortages and hunger, including 600 million in Africa alone (IPCC). Severe weather events and resulting disasters are becoming increasingly common and climate change impacts will have serious implications for public health globally. As the Center for Naval Analysis and others have noted, climate-related impacts will also have broad ramifications for stability and security in some of the most politically volatile regions in the world.

Agriculture is the economic sector most at risk to climate impacts – and the sector in which the consequences of global warming will affect the lives of the greatest number of people. The recent rapid increase in world food prices illustrates the human consequences of food scarcity that will be exacerbated by climate change – and may already be related to climate impacts in some cases.

The Costs of Inaction
The costs of failing to act to address both the already realized effects of global warming and the need to dramatically reduce carbon emissions to limit future effects are substantial and rapidly growing. The adaptation needs of developing countries have been estimated at upwards of $80 billion annually. The financial benefits from taking preventive action are great. According to an analysis by the U.S. Geological Survey and the World Bank, an investment of $40 billion to reduce disaster risk is capable of preventing disaster losses of $280 billion.

Opportunities Presented by the Climate Challenge
Working with vulnerable communities in building their resilience to the consequences of climate change can encourage these same communities to become more economically, socially and politically resilient in the broadest sense. Reliable access to essential services such as sanitation and clean water can help build the capacity of communities to respond to unpredictable climate events but also can promote economic growth and development. For many companies, there are critical overlaps between climate impacts that will affect their supply chains and impacts on local communities. Climate change may present new business opportunities and spur economic development in some of the poorest regions of the world.

Ms. BALDWIN. Thank you. Dr. McKitrick, you are next.

STATEMENT OF ROSS MCKITRICK, ASSOCIATE PROFESSOR AND DIRECTOR OF GRADUATE STUDIES, DEPARTMENT OF ECONOMICS, UNIVERSITY OF GUELPH

Mr. MCKITRICK. Thank you, Madam Chairwoman and subcommittee members. I am an Associate Professor of Economics at the University of Guelph in Canada, where I specialize in environmental economics and climate change. I have submitted an extended written testimony, where I discuss a lot of aspects of today's hearing. For my verbal presentation, I just want to highlight three points.

The first is that cost-benefit analysis as it has played out over the last few years in the economics literature simply doesn't provide support for deep emission cuts at this time. The Stern Review was not the first time that the economic consequences of global warming were studied. One recent tally points out that it is number 211 in a long series. There have been hundreds of studies looking at the economic consequences if climate-model projections are true. The median costs that emerge from these studies on a per-tonne basis fall in the range of about $0 to $20, and because there are relatively few abatement policies available in that range, cost-benefit analysis does not support deep emission cuts. The Stern Review, as has been noted, used some methodology and assumptions to generate much higher estimates of the per-tonne costs and fairly low estimates of the abatement costs. Those assumptions have been subject to quite a bit of criticism in the economics literature, not simply the discounting assumption, but other methodologies as well, and I think the Stern Review has been convincingly shown to be an unreliable guide for decision-making.

The second point is that if you do choose to act, cap-and-trade is a poor instrument for controlling CO_2 emissions. There have been a lot of studies comparing carbon taxes to cap-and-trade instruments. Cap-and-trade, for the same outcome, costs many times more than what a carbon tax would. Cap-and-trade, you should understand, is basically a cartel-forming device. It allows a group of energy producers in this case to restrict output, raise consumer prices, and pocket windfall gains as a result. One study showed that the distortions in the economy from cap-and-trade would be so severe that the very first tonne of emission reduction would begin at a cost between $20 and $55 a ton. So if you do choose cap-and-trade, you have to believe that the marginal damages of CO_2 emissions are at least as high as that; otherwise, you are guaranteed to make people worse off by implementing it.

The third point, my final point in summation, is that the stringency of any policy that you implement should be tied to the severity of the problem, and the severity should be measurable. It cannot be based on impressions formed by anecdotes or scare-stories, or for that matter offhand dismissals of the problem. There must be some measurable aspect to this that determines how severe a problem it is.

So if, for instance, you should go with what I think is the mainstream economics view, the only policy that could be justified at this time would be a low carbon tax. Now, in the future, the carbon tax might be expected to go up, but there is no agreement at what rate it should go up. I would suggest, and I have argued in a number of publications, that future increases in any carbon tax should be tied to the actual, observed mean temperature in the atmosphere. That way, if the people who are concerned about the greenhouse gasses are right, the carbon tax would go up rapidly in the years ahead, and you would get steady emissions reductions as a result. On the other hand, if greenhouse gasses are not really causing much global warming, then the tax won't rise, nor should it—either way, the severity of the problem guides the policy response, and I think it is a common principle in any policy undertaking that you tie the stringency of the policy to the severity of the problem, and I would remind you that that principle should apply in this case as well. Thank you.

[The prepared statement of Mr. McKitrick follows:]

United States House of Representatives
Subcommittee on Energy and Air Quality

Hearings, June 26 2008
"Climate Change: Costs of Inaction"

Washington DC

Testimony by

Ross McKitrick, Ph.D.
Associate Professor
Department of Economics
University of Guelph

CONTENTS

Section 1 Spoken testimony

My name is Ross McKitrick. I am an Associate Professor of Economics at the University of Guelph in Ontario. I hold a Ph.D. in economics from the University of British Columbia. My areas of specialization are environmental economics and climate change.

The term "costs of inaction" (on climate change) is an alternative label for what are more commonly referred to by economists as the *expected total damages* associated with greenhouse gas emissions. Estimation of total damages does not, on its own, provide a basis for policy analysis. Simply noting that a type of emissions may have social costs associated with them does not justify any and all policies proposed to reduce them. Some policies impose higher costs than the problems they are supposed to alleviate.

For this reason, economic analysis requires some further steps.

- A specific policy option must be outlined as the alternative to "inaction." In other words, if action is to be recommended over inaction, the specific form of the action needs to be defined and evaluated.
- The cost of inaction needs to be estimated in marginal, rather than total, terms. Decision-makers have control only over "one more unit" of emissions, i.e. *marginal* emissions, as opposed to total emissions and the damages that might be associated with them.
- Likewise, costs of the proposed course of action must be evaluated at the margin. Greenhouse gas controls can be defined over a range of strictness. Beyond the optimal point, further tightening of the policy causes higher economic costs than the value of the reduction in environmental damages.

A considerable amount of work has gone into estimating potential economic consequences of global warming induced by greenhouse gas emissions. The following points emerge from this analysis.

- The Stern Review was not, as many media sources claimed, a novel undertaking. It was number 211 in chronological sequence.
- The Stern Review's estimate of the marginal social costs of greenhouse gas emissions is far outside the mainstream view. It is even an outlier compared to non-peer reviewed studies that use low discount rates. It has been subject to extensive criticism by a large number of economists
- Average estimates of the marginal social cost of greenhouse gas emissions have declined over time. Estimates published prior to IPCC (1995) were larger than those published between IPCC (1995) and IPCC (2001). These, in turn, were larger than estimates

published between IPCC (2001) and IPCC (2007). Hence the IPCC's claim that more recent estimates of the cost of climate change are increasing is unsupported by the data.

- The median estimate among peer-reviewed studies that use a 3% discount rate (pure rate of time preference) is $20 per tonne of carbon. The mean is $23 per tonne.

The academic literature has shown a number of consistent findings about the marginal costs of greenhouse gas abatement.

- Command-and-control measures are the most costly and the least effective. Economic instruments like emission taxes and tradable permits are cheaper.

- Cap-and-trade programs are more damaging to the economy than emission taxes. Cap-and-trade creates a cartel among the permit holders, allowing them to force up consumer prices and earn windfall profits. One study found that reducing US greenhouse gas emissions by 5% using cap-and-trade would cost 10 times as much as using a revenue-neutral carbon tax.

- The monetary value of permits trading systems is not new wealth, it is a measure of the wealth transfers created by the policy. When industry leaders lobby for a cap-and-trade system, they are asking the government to create a highly profitable industry cartel that would be illegal for them to create themselves.

In my written submission I discuss in detail the baseline-minus-control analysis done by the Energy Information Administration for the Lieberman-Warner bill.

Specifying the baseline requires assumptions about the factors that drive emissions growth. Note that total emissions of greenhouse gases (GHG) can be broken down into three factors:

- *Emissions Intensity of the Economy* (GHG/GDP)
  - Total GHG emissions per dollar of Gross Domestic Product (GDP) is called "emissions intensity".

- *Real Average Income* (GDP/Pop)
  - The total amount of GDP divided by population determines real average income.

- *Population* (Pop)
  - The number of people in the economy who have a share in income.

The annual percentage growth of GHG emissions is approximately equal to the sum of the annual percentage change in each of these three factors:

$$\%GHG = \%Pop + \%\frac{GHG}{GDP} + \%\frac{GDP}{Pop}.$$

Hence, to specify a baseline requires making assumptions about these growth rates. The historical rates of growth of these three factors for the USA are:

- Pop: From 1960 to 2005, US population grew at an average annual rate of **+1.1%** per year.

- GDP/Pop: from 1960 to 2005 US Real Average Income (real GDP per capita) rose at an average annual rate of **+2.2%** per year.

- GHG/GDP: From 1960 to 2005 US CO_2 emissions intensity fell at an average annual rate of **1.7%** per year.

Added up, these rates yield the observed average annual growth in total CO_2 emissions of +1.6% per year:

$$1.1 + 2.2 - 1.7 = \mathbf{+1.6\%}.$$

Any proposal to reduce US greenhouse gas emissions has to explain where the reductions will come from. If income and population continue to grow at their historical levels, emissions intensity would have to fall twice as fast as its historical rate just to cap total emissions.

I note that the EIA assumed slower growth in both population and real income than the historical pattern when computing baseline emissions. As a result they forecast a much smaller gap between business-as-usual emissions and the Lieberman-Warner target than if they had used historical trends. In my view this caused them to understate the costs of reaching the target. They also applied an assumption in one of their scenarios that the US could introduce 313 Gigawatts of wind energy by 2030—more than the current capacity for coal generation—with almost no effect on real per capita income. This strikes me as implausible.

Finally, I offer a few comments by way of summation.

1. **Costs of climate policy cannot be wished away.**
   It is important to dispense with any illusion that large reductions in greenhouse gas emissions in the near future will be cheap and/or easy. A policy that doesn't cost much will accomplish little. For this reason, it would be entirely reasonable to conclude that you are not prepared to impose the economic damage required to achieve major emission reductions.

2. **Cap and trade is not a good fit with carbon emissions.**
   Policymakers impressed with the success of the Acid Rain control program may instinctively jump on the cap-and-trade bandwagon. But achieving greenhouse gas reductions is not like

reducing sulfur dioxide, because there are so few options for CO_2 abatement. There is a widespread view among environmental economists that cap-and-trade would be a poor instrument choice for climate policy.

3. **Any tax on carbon emissions should start low.**
Another point of broad agreement among economists is that any carbon tax should begin at a low level, perhaps around $20 per tonne. But at this rate, very little emissions reductions would occur. Hence, another way of expressing this point is that the economics does not favor deep emission reduction targets at this time.

4. **A tax on carbon emissions should only go up if the atmosphere actually warms.**
Some analysts argue that the carbon tax should automatically rise over time. The case for increasing the tax rests on a lot of modeling assumptions about the climate response to greenhouse gases that I think are premature. I have proposed instead that the tax should be tied to an actual indicator of global warming The IPCC and the Climate Change Science Program have both shown that if greenhouse gases really affect the climate, then there will be a unique signature on the atmosphere in the form of a strong warming trend about ten miles over the equator, in the so-called tropical troposphere. Hence the tropical troposphere is our best 'canary in the coal mine.'

The IPCC report examined 25 years of data from weather satellites and weather balloons, and found no evidence of a significant warming trend in the tropical troposphere. Satellite data from the University of Alabama-Huntsville shows a trend of only 0.06 ^{o}C/decade in the tropics, which is statistically insignificant.

The trouble with most greenhouse gas policy ideas being pitched to governments is that they only begin to make sense if the worst-case warming scenarios are right. If these scenarios are wrong, the policies are truly misguided. I believe you should look for a policy that makes sense no matter who is right.

Suppose you implement a low carbon tax and calibrate it to the mean temperature of the tropical troposphere. If the temperature starts going up, the tax would go up, forcing emissions down. If the tropical troposphere does not warm up, the tax won't go up, nor should it. People on all sides of the issue would expect to get their preferred outcome.

Such a tax would cause investors to build long term expectations about future climate change into today's decision-making. Someone building a pulp mill or a power plant would have to get the best information available about climate trends for the next ten or twenty years, in order to project the carbon price they will face. This will also create a market for accurate climate forecasts, injecting a dose of reality into academic studies. It will also mean that the policy outcome is rooted in reality. Whether the tax goes up enough to really force emissions down will ultimately depend on whether greenhouse gases are a problem. We will end up with the right outcome, without having to guess in advance what the right policy is. The alternative is a giant political struggle over whose speculations about the future climate are more likely to be right.

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Section 2 Background Discussion

The "Costs of Inaction" versus the Net Marginal Benefits of a Proposed Policy

The term "costs of inaction" (on climate change) is an alternative label for what are more commonly referred to by economists as the *expected total damages* associated with greenhouse gas emissions. Estimation of total damages does not, on its own, provide a basis for policy analysis. Simply noting that a type of emissions may have social costs associated with them does not justify any and all policies proposed to reduce them. In much the same way, simply noting that a particular country poses a potential military threat does not justify any and all proposed responses. Some responses impose higher costs than the problems they are supposed to alleviate.

For this reason, economic analysis requires some further steps.

- A specific policy option must be outlined as the alternative to "inaction." In other words, if action is to be recommended over inaction, the specific form of the action needs to be defined and evaluated.
- The cost of inaction needs to be estimated in marginal, rather than total, terms. We only ever cause increments of damage. Nobody is in a position to take responsibility for, or alleviate, all damages—past, present and future—associated with greenhouse gas emissions. Decision-makers have control only over "one more unit" of emissions, i.e. *marginal* emissions, as opposed to total emissions and the damages that might be associated with them.
- Likewise, costs of the proposed course of action must be evaluated at the margin. Greenhouse gas controls can be defined over a range of strictness, ranging from less than a 1% reduction to a complete ban. The optimal degree of strictness is defined as the point where the marginal costs of tightening the policy just equal the marginal damages of the emissions. Beyond that point, further tightening of the policy causes higher economic costs than the value of the reduction in environmental damages.

In order to identify the optimal policy, economists look at the *net marginal benefits* of a proposed policy instrument. The term 'net' means that we are interested in the environmental benefits of the policy over and above the economic cost of implementing it. The term 'marginal' is a reminder that we are always starting from the status quo: we are never in a position to rewrite history or prescribe a path whose starting point is unconnected to the current economy or state of technology.

Marginal Damages of GHG's

A considerable amount of work has gone into estimating potential economic consequences of global warming induced by greenhouse gas emissions. Tol (2007) presents a survey of 211 estimates of the marginal cost of greenhouse gas emissions, expressed as dollars per tonne of carbon-equivalent. The following points emerge from his analysis.

- The Stern Review was not, as many media sources claimed, a novel undertaking. It was number 211 in chronological sequence.
- Studies in the 'gray' literature – i.e. non-peer reviewed – report higher cost estimates than peer-reviewed studies. Peer review is a guard against fearmongering.
- Studies that use inappropriately low discount rates estimate higher costs than those that use conventional discount rates.
- The Stern Review's estimate of the marginal social costs of greenhouse gas emissions is far outside the mainstream view. It is even an outlier compared to non-peer reviewed studies that use low discount rates. It has been subject to extensive criticism by a large number of economists (e.g. Weitzman 2007, Tol and Yohe 2006, Tol 2006, Mendelsohn 2008, Dasgupta 2006, Byatt et al. 2006, Nordhaus 2007, Beckerman and Hepburn 2007, etc.)
- Average estimates of the marginal social cost of greenhouse gas emissions have declined over time. Estimates published prior to IPCC (1995) were larger than those published between IPCC (1995) and IPCC (2001). These, in turn, were larger than estimates published between IPCC (2001) and IPCC (2007). Hence the IPCC's claim that more recent estimates of the cost of climate change are increasing is unsupported by the data.
- Because there is an upper tail of very high cost estimates, cost-benefit analysis will be highly influenced by the weight attached to the risks associated with the upper tail.
- The median estimate among peer-reviewed studies that use a 3% discount rate (pure rate of time preference) is $20 per tonne of carbon. The mean is $23 per tonne.

Nordhaus (2007b) uses integrated assessment modeling to derive the discounted present value of the marginal social damages of greenhouse gas emissions. He puts the cost at about $17 (US) per tonne of carbon.

My own opinion is that figures like $17-23 per tonne are too high. Tol (2007) notes that many studies assume a static economic environment in which people do not adapt or change in response to climatic changes. This is one way in which the costs can be overstated. Also, the modeling assumptions take for granted the distribution of warming scenarios in IPCC reports. My work on the surface temperature record (McKitrick and Michaels 2004, 2007) shows that the land-based warming record is substantially exaggerated. The UAH satellite temperature record from the tropical troposphere[1] exhibits a statistically insignificant trend of about 0.06 °C/decade

[1] Data from http://vortex.nsstc.uah.edu/public/msu/t2lt/tltglhmam_5.2.

since 1979, yet in all climate models this atmospheric region is supposed to exhibit the maximum warming response to greenhouse gases. This suggests to me that many climate models are programmed with overly high greenhouse gas sensitivity parameters.

However, nothing in the discussion presented below turns one way or the other on this issue. Readers can form their own opinions on the value of the marginal social damages of greenhouse gas emissions. The key point is to realize that the number is not infinite, and that a great deal of research over the past few decades has largely indicated that the dollar values on a per tonne basis are not especially large at this time.

Costs of Abatement

There are two commonly-used ways of evaluating the costs of abatement policies. The first is to compute the marginal abatement costs associated with specific policies, starting from the present time. The is the approach most commonly applied in the academic economics literature since it allows for comparative calculations of the costs of different approaches. The second is to compute a macroeconomic 'baseline-minus-control' simulation for many decades ahead, in order to estimate the total implementation costs of a specific policy mix out to some specified time. This approach uses some of the information generated by the first method, but is also dependent on ad hoc modeling assumptions. It is used by agencies such as the Energy Information Administration to provide policymakers with estimates of the macroeconomic impacts of policies like the Lieberman-Warner Climate Security Act (S.2191).

Marginal Abatement Cost Estimates

Economists use the general equilibrium framework to examine the costs and benefits of policy changes (see, e.g., Shoven and Whalley 1992, McKitrick 1997). The appropriate measure of net benefits is a monetary equivalent of consumer utility, after the economy has fully adjusted to the policy change. Policymakers often want to know the results in terms of changes to GDP. While this statistic matters, focusing on it can also mask important changes. Some policies can raise GDP but make everyone worse off, if people have to work harder to maintain the same standard of living. When presented with estimates of GDP change, always ask to see the estimated changes in real per capita consumption, since this is a better measure of the economic consequences of the policy.

General equilibrium analysis is important because it allows us to examine how a change in one sector (e.g. energy) affects other sectors, and also allows us to study the interactions among different policies. Sometimes introduction of a new policy exacerbates costs associated with older policies—this is an important finding with respect to greenhouse gas abatement.

Much of the underlying theory for analysis of environmental policy was spelled out in Sandmo (1977) and Baumol and Oates (1988) Studies that have used numerical general equilibrium models to look at the costs of reducing air emissions in the US include Bovenberg and Goulder (1996), Parry et al. (1999) and Goulder et al. (1999). From these and many other studies (e.g. McKitrick 1998), a few key insights have repeatedly emerged.

- Different policies for achieving the same emissions reduction can have very different costs. Command-and-control measures are the most costly and the least effective. Economic instruments like emission taxes and tradable permits are cheaper. Revenue-neutral emission taxes are the cheapest, as long as all the revenue is refunded via reductions in taxes on income or investment. If the revenue is used to subsidize abatement expenses (i.e. through grants for alternative energy) much of the economic efficiency is lost.

- Cap-and-trade programs are more damaging to the economy than emission taxes (Elkins and Baker 2001). Cap-and-trade creates a cartel among the permit holders, allowing them to force up consumer prices and earn windfall profits. This not only imposes direct costs, but it creates a large class of hidden costs because of the way the increased energy costs and reduced real wages amplify the economic costs of the pre-existing tax system. Such costs can only be detected using general equilibrium modeling, and they are significant. Parry et al. (1999) estimate that reducing US greenhouse gas emissions by 5% using cap-and-trade would cost 10 times as much as using a revenue-neutral carbon tax.

- Cap-and-trade is also regressive, since higher energy prices fall disproportionately on the poor. Carbon taxes can alleviate this more easily since the offsetting tax reductions can be directed towards low-income houses.

- It is a fallacy to refer to the monetary value of permits trading systems as a new market to be exploited. Instead, the value of permits being traded is a measure of the wealth transfers created by the policy. For example, if the US uses cap-and-trade to reduce its CO_2 emissions to 1.2 Gigatonnes (the Kyoto target), and the permits end up costing $100 each, the windfall gain to permit holders would be $120 billion. *This is not new wealth*, instead it is the transfer of wealth from the general public to the members of the newly-created cartel who hold the permits. When industry leaders lobby for a cap-and-trade system, they are asking the government to create a highly profitable industry cartel that would be illegal for them to create themselves.

- Cap-and-trade systems for greenhouse gases would likely impose marginal economic costs on the US of between $18 and $55 per tonne for the first tonne of abatement (Parry et al. 1999, Bovenberg and Goulder 1996). The costs would rise from there, roughly doubling for every 10% additional emissions reduction. Consequently, unless the marginal damages of greenhouse gas emissions are believed to be higher than the $18-55 range, cap-and-trade should be ruled out, since it is guaranteed to make the US worse off, even taking into account generous estimates of the benefits of reducing greenhouse gases.

- When uncertainty is taken into account, the case for using a price instrument, e.g. a carbon tax, rather than a quantity instrument like cap-and-trade, becomes even stronger (Nordhaus 2007b, 2006; Newell and Pizer 2003, Parry 2003; etc.) Policymakers can set an emissions cap, and let the market choose the price, or choose a price and let the market choose the emissions level. Either way, uncertainty means that policymakers are, by necessity, taking a guess at the optimal price or quantity target, and will undoubtedly make a mistake. In the case of carbon dioxide emissions, mistakes on the quantity axis have much higher expected economic costs than mistakes on the price axis. It is better for policymakers to decide what they believe the marginal damages of carbon emissions are, and then set that amount as a price, rather than imposing an emissions cap and hoping the permits market doesn't lead to prices far in excess of that amount.

Baseline-minus-control scenarios

In a baseline-minus-control approach, the modeler estimates what the emissions will be out to some distant target date, such as 2030. Then the cap prescribed by a policy instrument is imposed, and the model is re-run under various assumptions about how the cap will be achieved.

Specifying the baseline requires assumptions about the factors that drive emissions growth. Note that total emissions of greenhouse gases (GHG) can be broken down into three factors:

- *Emissions Intensity of the Economy* (GHG/GDP)
  - Total GHG emissions per dollar of Gross Domestic Product (GDP) is called "emissions intensity".
- *Real Average Income* (GDP/Pop)
  - The total amount of GDP divided by population determines real average income.
- *Population* (Pop)
  - The number of people in the economy who have a share in income.

These factors, multiplied together, yield total annual emissions:

$$GHG = \frac{GHG}{GDP} \times \frac{GDP}{Pop} \times Pop$$

Note: this is not a theory or an economic model, it is a mathematical identity that must hold true.

Mathematically, this means that the annual percentage growth of GHG emissions is approximately equal to the sum of the annual percentage change in each of these three factors:

$$\%GHG = \%Pop + \%\frac{GHG}{GDP} + \%\frac{GDP}{Pop}.$$

Hence, to specify a baseline requires making assumptions about these growth rates. The historical rates of growth of these three factors for the USA are:

- Pop: From 1960 to 2005, US population grew at an average annual rate of **+1.1%** per year.[2]
- GDP/Pop: from 1960 to 2005 US Real Average Income (real GDP per capita) rose at an average annual rate of **+2.2%** per year.[3]
- GHG/GDP: From 1960 to 2005 US CO_2 emissions intensity fell at an average annual rate of **1.7%** per year.[4]

Added up, these rates yield the observed average annual growth in total CO_2 emissions of +1.6% per year:

1.1 + 2.2 - 1.7 = **+1.6%** .

Note: CO_2 comprises 95% of US emissions covered by the Lieberman-Warner bill.

From this analysis we can see that future growth in CO_2 emissions will be driven by future population growth + future income growth + future change in emissions intensity. To assess the credibility of any cost estimates it is essential to examine the assumptions made about each of these factors.

To get some sense of the scale of challenge involved in the Lieberman-Warner bill, note that it required an annual average reduction in total GHG emissions (subject to partial attainment through offsets) of

- - 1.1% per year on average between 2006 and 2012
- - 1.9% per year on average between 2006 and 2030
- - 2.9% per year on average between 2006 and 2050

If the US Congress intends that population growth should continue to average +1.1% per year, and real income growth should continue to average +2.2% per year, S.2191 would have required emissions intensity to decline by the following approximate amounts:

- - 4.4% per year on average between 2006 and 2012
- - 5.2% per year on average between 2006 and 2030
- - 6.2% per year on average between 2006 and 2050

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[2] http://www.gpoaccess.gov/eop/tables07.html
[3] http://www.gpoaccess.gov/eop/tables07.html
[4] http://cdiac.esd.ornl.gov/ftp/trends/emissions/usa.dat and http://epa.gov/climatechange/emissions/downloads06/07ES.pdf for CO2 emissions; GDP at http://www.gpoaccess.gov/eop/tables07.html

There is no historical precedent for such rapid reductions in CO_2 emissions intensity. Nor is there any explanation in the legislation of how this reduction in emissions intensity is to be achieved, especially if, as is likely, international offsets are not a reliable option.

Comparison to Sulfur Dioxide Market

Some commentators point to the dramatic reduction in sulfur dioxide emissions under the Clean Air Act Amendments as a good analogue to what can be done with CO_2. However the situations are very different. According to EPA data,[5] total US sulfur dioxide emissions fell by approximately 50% between 1970 and 2002. However, about half these reductions occurred through use of scrubbers and about half from switching to low-sulfur coal, following railway de-regulation in the 1990s (Schmalensee et al. 1998). Neither of these strategies are applicable to greenhouse gas abatement.

- There are no scrubbers for CO_2 . Even if the gas can be stripped from smoke, it cannot be disposed of or used as an industrial feedstock, since that will just delay its eventual release. It must be pumped underground (carbon capture and storage, or CCS), which is costly and rarely feasible.

- While it is possible to find low-sulfur coal or oil, there is no such thing as low-carbon coal or oil.

The only way to reduce CO_2 emissions on a large scale is to reduce fossil energy consumption or switch fuel types, such as from coal to natural gas. These are much more expensive methods than scrubbers or source switching. This is why they did not play much role in reducing sulfur dioxide emissions under Acid Rain regulations, and that is why cost estimates for reducing CO_2 emissions are higher than those for sulfur emissions.

Baseline assumptions in the EIA Analysis

The analysis of the Energy Information Administration[6] is generally seen as yielding high cost estimates for the Lieberman-Warner bill. However, a close look shows that their key assumptions probably understate what the implementation costs would have been.

- In the EIA analysis, Population was assumed to grow at an average rate of +0.9% per year from 2006 through 2030 in all scenarios, four-fifths the average growth rate experienced since 1960. This assumption reduces the base case emission levels in the absence of legislation, thereby artificially reducing the cost of reaching the target. Unless the US Congress has adopted, or plans to adopt, a policy of sharply restricted immigration, this assumption is inappropriate. Cost estimates should have been presented assuming +1.1% population growth in the future. This would likely have increased the estimated macroeconomic costs of S.2191 by at least 20%.

[5] http://www.epa.gov/ttn/chief/trends/index.html and http://www.epa.gov/ttn/chief/trends/trends98/index.html

[6] Available at http://www.eia.doe.gov/oiaf/servicerpt/s2191/index.html. References to spreadsheets are to those on this page.

- In the EIA analysis, real per capita income in the base case was assumed to grow at an average rate of +1.6% per year after 2006, less than three-quarters the average growth rate experienced since 1960. This assumption reduces the base case emission levels in the absence of legislation, thereby artificially reducing the cost of reaching a target. Unless the US Congress has adopted a goal of permanently reducing real income growth, this assumption is inappropriate. Cost estimates should have been presented assuming base case +2.2% real income growth in the future. This would likely have increased the estimated macroeconomic costs of S.2191 by at least 30%.

- In the EIA analysis, by scaling down assumed population and income growth, the estimated base case GHG emissions in the US after 2006 grow at an annual rate of only +0.7% through 2020 and +0.4% through 2030.[7] Since the observed historical annual growth rate in US emissions since 1960 is +1.6% per year, the EIA analysis assumed away half to three-quarters of potential future growth in GHG emissions. In my view this had the effect of sharply reducing the estimated policy compliance costs. It was misleading to present such estimates without also presenting information about how the costs would increase if future business-as-usual emission trends follow historical trends. Such estimates would likely have at least doubled the cost estimates reported by the EIA.

- Even more remarkably, in the EIA analysis, none of the implementation scenarios for S.2191 had much effect on the resulting annual average rate of growth of real per capita income. The following table lists the results for the base case and three scenarios, encompassing the cheapest ("Core") and the costliest ("Limited Alternatives and No International Offsets").[8]

Growth in real GDP per capita	Compared to 2006 Total % Change		Compared to 2006 Annual Avg % Chg	
EIA Scenario:	**2020**	**2030**	**2020**	**2030**
Base Case	24.8%	44.7%	1.6%	1.6%
"Core" - Cheap and Easy Alternatives	24.4%	44.7%	1.6%	1.6%
Limited Alternatives	24.2%	44.1%	1.6%	1.5%
Limited Alternatives and No Int'l Offsets	23.6%	43.9%	1.5%	1.5%

In all cases, real average income continues to grow at the base case rate (+1.6%) or just under. Despite the enormous price shocks experienced under the policy scenarios, and despite the massive diversion of resources required to restructure much of the US energy system towards nuclear or renewables, the EIA model predicts no income effects. This is simply not credible, and flies in the face of ample historical evidence concerning past energy price shocks. With this assumed structure the EIA model would not be able to account for the recessions experienced in response to past energy price shocks, and it therefore likely underestimated the economic consequences of future policy-induced price shocks. At the

[7] Reference spreadsheet line 1865.
[8] Lines 1758 and 1795 from relevant case spreadsheets.

very least the EIA should have provided sensitivity analyses to demonstrate how their cost estimates would have changed if major energy price increases were allowed to affect the economic growth assumptions in their economic model. This would obviously have led to much larger economic cost estimates for S.2191.

- In the *least cost* scenario ("Core"), EIA modelers assumed that the USA can increase its nuclear power capacity by 26% between now and 2020, and by an astonishing 267% between 2020 and 2030. This requires that in the decade after 2020 the US could flawlessly bring online two new nuclear reactors for every one operating as of 2020. By historical standards this is very implausible, especially in light of the decades-long failure to open the proposed nuclear waste storage facility at Yucca Mountain. The EIA ought to have conducted sensitivity analyses of additional costs likely to be incurred under the "Core" scenario if the massive additions to nuclear capacity cannot occur on the stated schedule.

- In the *highest cost* EIA scenario ("LA – NoInt"), new nuclear power does not become available. However, this does not address the implausibility of the Core scenario since the EIA substitutes in the equally implausible assumption that 313 Gigawatts of continuous wind energy will become available,[9] more than the entire current coal-fired generating capacity (305 Gigawatts). But wind energy is neither scalable during peak hours nor continuously available, so it is unrealistic to assume it can displace that much fossil generation in just over two decades. Even under this unrealistic assumption, domestic energy costs go up by 180%[10] and 1 million jobs in manufacturing are eliminated.[11]

In sum, key assumptions about the baseline, and about the ease of implementing specific policy scenarios, likely understated the economic costs in the EIA analysis of S.2191 by about half. The EIA should be asked to do any future analyses of major climate change legislation applying the assumption of future population growth of +1.1% per year and base-case real income growth of +2.2% per year; and they should be asked to put realistic limits on the extent to which wind and nuclear energy can replace coal.

Some Policy Conclusions

I would like to present a few summary conclusions to guide you in your search for the best climate change policy.

1. **Costs of climate policy cannot be wished away.**
   It is important to dispense with any illusion that large reductions in greenhouse gas emissions in the near future will be cheap and/or easy. Under current US energy technology, any emissions reduction large enough to "count" will be large enough to hurt, possibly badly. A policy that doesn't cost much will accomplish little in terms of emission

[9] Limited/No International spreadsheet lines 1532-33.
[10] Limited/No International spreadsheet line 1775.
[11] Limited/No International spreadsheet line 1797.

reductions and virtually nothing in terms of actual climate effects. For this reason, it would be entirely reasonable to conclude that you are not prepared to impose the economic damage required to achieve major emission reductions. A straightforward comparison of costs and benefits supports this position, with the caveat that action may be justified to speed up technological innovations in low-emission energy sources, as long as the new technologies have a realistic prospect of being economically competitive in a reasonable period of time. Beyond that, it is quite defensible to conclude that the costs of any actions open to you exceed the costs of inaction. In any case, do not try to wish away the dilemma by pretending emission reductions won't be costly.

For instance, The Natural Resources Defence Council (NRDC) has claimed Lieberman-Warner could be attained at very low costs, and in many cases households and firms would be better off.[12] Their reports demonstrate the error described above by describing the revenues raised from emission permit sales as new wealth. They list the tens of billions of dollars in new Congressional subsidies for money-losing alternative energy projects and political rent-seeking, and repeatedly refer to this as "new" money or "new" investments.[13] It is nothing of the sort. These funds are transfers away from existing consumers and firms to the government for redistribution, in effect a set of hidden taxes. And since taxes always generate deadweight losses—i.e. more wealth is destroyed by implementing the tax than is generated for the government to spend or redistribute—the permits revenue from S.2191 represents an overall destruction of wealth, not a source of new wealth.

Moreover, the NRDC apparently does not believe its own claims. They have argued that reductions in GHG emissions sufficient to yield compliance with S.2129 could be implemented by the private sector at low or no cost.[14] If so, then a nominal carbon emissions tax at, say, five dollars per tonne of carbon equivalent, would be more than enough to induce full compliance. If firms really are better off implementing the emission reductions they don't need the threat of fines and jail terms to make them do it. But when it has been suggested that a low safety valve price should be added to cap-and-trade legislation, the NRDC objects,[15] claiming that a strict cap with a high permit price is necessary to force emission reductions. Hence they contradict the conclusions of their own economic analysis. They don't believe their own analysis, and neither should anybody else. Greenhouse gas emission reductions will be costly, especially if the implementation relies on command-and-control or cap-and-trade approaches.

2. **Cap and trade is not a good fit with carbon emissions.**
   Policymakers impressed with the success of the Acid Rain control program may instinctively jump on the cap-and-trade bandwagon. But achieving greenhouse gas reductions is a different situation than achieving sulfur dioxide emission reductions, primarily because there are so few options for reducing CO_2 emissions. Those differences matter, and have led to a

[12] See http://nrdc.org/globalWarming/liebwarner.asp.
[13] http://nrdc.org/legislation/factsheets/leg_08052701A.pdf.
[14] http://nrdc.org/legislation/factsheets/leg_08051401A.pdf.
[15] http://www.nrdc.org/legislation/factsheets/leg_07032601A.pdf.

widespread view among environmental economists that cap-and-trade would be a poor instrument choice for climate policy.

3. **Any tax on carbon emissions should start low.**
Another point of broad agreement among economists is that any carbon tax should begin at a low level. Nordhaus (2007) suggests $17 per tonne. Using the data from Tol's survey we would get marginal damages of about $20, then applying the adjustment derived by Sandmo (1977), which requires us to divide the marginal damages by the marginal cost of public funds, we would get a figure of about 20/1.4 = $14.30. Personally I think even this is too high, but for the sake of argument suppose that carbon tax were implemented. At this rate, very little emissions reductions would occur. Hence, another way of expressing this point is that the economics does not favor adopting deep emission reduction targets at this time.

4. **A tax on carbon emissions should only go up if the atmosphere actually warms.**
Nordhaus and others argue that the carbon tax should automatically rise over time. The case for increasing the tax rests on a lot of modeling assumptions about the climate response to greenhouse gases that I think are premature. I have proposed instead that the tax should be tied to an actual indicator of global warming (McKitrick 2007a,b). The IPCC and the Climate Change Science Program have both shown in their modeling work (IPCC 2007 Fig 10.7, CCSP 2006 Fig. 5.7) that if greenhouse gases really affect the climate, then there will be a unique signature on the atmosphere in the form of a strong warming trend about ten miles over the equator, in the so-called tropical troposphere. Of all the factors that might cause warming in the future, only greenhouse gases will yield a big relative warming there, and according to the IPCC it will be rapid, and will be stronger than warming at the surface (IPCC 2007 pp. 714-715). Also, if carbon emissions really drive climate change, models show the trend should already be well underway (IPCC Fig. 9.1, CCSP Fig. 1.3). Hence the tropical troposphere is our best 'canary in the coal mine.'

So it is noteworthy that the IPCC report examined 25 years of data from weather satellites and weather balloons, and found no evidence of a significant warming trend in the tropical troposphere. Satellite data from the University of Alabama-Huntsville shows a trend of only 0.06 °C/decade in the tropics, which is statistically insignificant. The average temperature has drifted upwards since 1980, but not beyond the bounds of natural variability. The CCSP noted this too, and pointed out that the models showing the greatest agreement with observations are those that have the lowest amounts of warming (CCSP p.11).

The trouble with the most greenhouse gas policy ideas being pitched to governments is that they only begin to make sense if the worst-case warming scenarios are right. I believe you should look for a policy that makes sense no matter who is right.

We have good quality data on the mean temperature in the tropical troposphere. Suppose you implement a low carbon tax with full revenue recycling to make it revenue-neutral. And suppose you calibrate the carbon tax rate to the mean temperature of the tropical troposphere. If greenhouse gases really drive climate change, the temperature will go up, and the tax would go up, forcing emissions down. If the tropical troposphere does not warm up, the tax won't go up, nor should it. People on all sides of the issue would expect to get their preferred outcome.

Such a tax would force investors to build long term expectations about future climate change into today's decision-making. Someone building a pulp mill or a power plant would have to get the best information available about climate trends for the next ten or twenty years, in order to project the carbon price they will face. This will create a market for accurate climate forecasts, injecting a dose of reality into academic studies. It will also mean that the policy outcome is rooted in reality. Whether the tax goes up enough to really force emissions down or not will ultimately depend on whether greenhouse gases are a problem. You will end up with the right outcome, without having to guess in advance what the right policy is. The alternative is a giant political struggle over whose speculations about the future climate are more likely to be right.

REFERENCES

Baumol, W. J., and W. E. Oates. 1988. *The Theory of Environmental Policy.* Cambridge University Press.

Beckerman, W., and C. Hepburn. 2007. Ethics of the Discount Rate in the Stern Review on the Economics of Climate Change. *World Economics* 8, no. 1: 187-210.

Bovenberg, A. L., and L. H. Goulder. 1996. Optimal environmental taxation in the presence of other taxes: General-equilibrium analyses. *American Economic Review* 86, no. 4: 985-1000.

Byatt, I., R. M. Carter, I. Castles, et al. 2006. The Stern Review: A Dual Critique. *World Economics* 7, no. 4: 165-232.

CCSP (Climate Change Science Program). 2006. *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences.* Thomas R. Karl, Susan J. Hassol, Christopher D. Miller, and William L. Murray, editors, 2006. A Report by the Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC.

Dasgupta, P. 2006. Comments on the Stern Review's Economics of Climate Change. *Disponible en www. econ. cam. ac. uk/faculty/dasgupta/Stern. pdf.*

Elkins, P., and T. Baker. 2001. Carbon Taxes and Carbon Emissions Trading. *Journal of Economic Surveys* 15, no. 3: 325-376.

Goulder, L. H., I. W. H. Parry, R. C. Williams III, and D. Burtraw. 1999. The cost-effectiveness of alternative instruments for environmental protection in a second-best setting. *Journal of Public Economics* 72, no. 3: 329-360.

Intergovernmental Panel on Climate Change (IPCC) Working Group I (1995) *Climate Change 1995: The IPCC Second Assessment Report.* Cambridge: Cambridge University Press.

Intergovernmental Panel on Climate Change. (2001), *Climate Change 2001: The Scientific Basis.* Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell and C.A. Johnson CA., eds. Cambridge: Cambridge University Press.

IPCC, 2007: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

McKitrick, Ross R. (2007a) The T3 Tax as a Policy Strategy for Global Warming. In Nakamura, A. ed. *The Vancouver Volumes* Trafford Press, forthcoming. Availble at http://ross.mckitrick.googlepages.com/.

McKitrick, Ross R. (2007b) Let Policy Follow Science: Tie a Carbon Tax to Actual Warming. (Christian Science Monitor December 3, 2007)

McKitrick, R. 1997. Double Dividend Environmental Taxation and Canadian Carbon Emissions Control. *Canadian Public Policy* 23, no. 4: 417-434.

McKitrick, R. R. 1998. The econometric critique of computable general equilibrium modeling: the role of functional forms. *Economic Modelling* 15, no. 4: 543-573.

McKitrick, R.R. and P.J. Michaels (2007), Quantifying the influence of anthropogenic surface processes and inhomogeneities on gridded global climate data, J. Geophys. Res., 112, D24S09, doi:10.1029/2007JD008465.

McKitrick, Ross and Patrick J. Michaels (2004). "A Test of Corrections for Extraneous Signals in

Gridded Surface Temperature Data" *Climate Research* 26 pp. 159-173.
Mendelsohn, Robert. 2008. Is the Stern Review an Economic Analysis? *Rev Environ Econ Policy* 2, no. 1 (January 1): 45-60. doi:10.1093/reep/rem023.
Newell, Richard G., and William A. Pizer. 2003. Regulating stock externalities under uncertainty. *Journal of Environmental Economics and Management* 45, no. 2, Supplement 1 (March): 416-432. doi:10.1016/S0095-0696(02)00016-5.
Nordhaus, W. D. 2006. After Kyoto: Alternative Mechanisms to Control Global Warming. *American Economic Review* 96, no. 2: 31-34.
Nordhaus, William. 2007. ECONOMICS: Critical Assumptions in the Stern Review on Climate Change. *Science* 317, no. 5835 (July 13): 201-202. doi:10.1126/science.1137316.
Nordhaus, William. 2007b. To Tax or Not to Tax: Alternative Approaches to Slowing Global Warming. *Review of Environmental Economics and Policy* 1, no. 1: 26.
Parry, I. W. H. 2003. Fiscal Interactions and the Case for Carbon Taxes Over Grandfathered Carbon Permits. *Oxford Review of Economic Policy* 19, no. 3: 385-399.
Parry, I. W. H., R. C. Williams, and L. H. Goulder. 1999. When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets. *Journal of Environmental Economics and Management* 37, no. 1: 52-84.
Sandmo, A. 1975. Optimal Taxation in the Presence of Externalities. *Swedish Journal of Economics* 77, no. 1: 86-98.
Schmalensee, R., P. L. Joskow, A. D. Ellerman, J. P. Montero, and E. M. Bailey. 1998. An Interim Evaluation of Sulfur Dioxide Emissions Trading. *Journal of Economic Perspectives* 12, no. 3: 53-68.
Shoven, J. B., and J. Whalley. 1992. *Applying General Equilibrium.* Cambridge University Press.
Stern, N. 2006. Stern Review on the Economics of Climate Change. *HM Treasury* 1: 2006.
Tol, R. S. J. 2006. The Stern Review Of The Economics Of Climate Change: A Comment. *Energy & Environment* 17, no. 6: 977-982.
Tol, R. S. J., and G. W. Yohe. 2006. A Review of the Stern Review. *World Economics* 7, no. 4: 233-50.
Weitzman, M. L. 2007. A Review of the Stern Review on the Economics of Climate Change. *Journal of Economic Literature* 45, no. 3: 703-724.

Ms. BALDWIN. Thank you. Next, Dr. Pielke.

STATEMENT OF ROGER A. PIELKE, SR., SENIOR RESEARCH SCIENTIST (CIRES), SENIOR RESEARCH ASSOCIATE (ATOC), UNIVERSITY OF COLORADO, BOULDER

Mr. PIELKE. My presentation is entitled "A Broader View of the Role of Humans in the Climate System as Required in the Assessment of Costs and Benefits of Effective Climate Policy." And I would like to start with the human addition of CO_2 in the atmosphere is a first-order climate forcing, and we need an effective policy to limit the atmospheric concentration of this gas. However, humans are significantly altering the climate system in a diverse range of ways, in addition to CO_2. The information that I am presenting will assist in properly placing CO_2 policy in the broader context of climate policy.

Climate policy is much more than just long-term weather statistics, but it includes physical, chemical, and biological components of the atmosphere, oceans, land surface, and glacial covered areas. In 2005, the National Research Council published a report, "Radiative forcing of climate change: expanding the concept and addressing uncertainties," and documented that a human disturbance of any aspect of the climate system necessarily alters other aspects of the climate.

The role of humans within the climate system must, therefore, be one of the following three possibilities: the human influence is minimal and natural variations dominate climate variations on all time scales; or while natural variations are important, the human influence is significant and it involves a diverse range of first-order climate forcings, including, but not limited to, the human input of CO_2; or the human influence is dominated by the emissions into the atmosphere of greenhouse gasses, particularly carbon dioxide. My written testimony presents evidence that the correct scientific conclusion is that the human influence on climate is significant and involves a diverse range of first-order climate forcings including but not limited to the human input of carbon dioxide.

Modulating carbon emissions as the sole mechanism to mitigate climate change, therefore, neglects the diversity of other important first-order climate forcings. As a result, a narrow focus only on carbon dioxide to predict future climate impacts will lead to erroneous confidence in the ability to predict future climate, and thus cost and benefits will be miscalculated. CO_2 policies need to be complemented by other policies focused on the other first-order climate forcings. In addition, the 2005 National Research Council report concluded that a global average surface temperature trend offers little information on regional climate change. In other words, the concept of global warming by itself does not accurately communicate the regional responses to the diverse range of human climate forcings. Regional variations in warming and cooling, for example, such as from aerosols and landscape changes, as concluded in the National Research Council report have important regional and global impacts on weather.

The human climate forcings that have been ignored or insufficiently presented in the IPCC and CCSP reports include the influence of human-caused aerosols on regional and global ratiative heating; the effect of aerosols on clouds and precipitation; the effect of aerosol deposition, such as from soot and nitrogen on climate; the effect of land-cover/land-use on climate; and the biogeochemical effect of added atmospheric CO_2. Thus, climate policy that is designed to mitigate the human impact on regional climate by focusing only on the emissions of carbon dioxide is seriously incomplete unless these other first-order human climate forcings are included or complementary policies for these other human climate forcings are developed.

Moreover, it is important to recognize that climate policy and energy policy, while having overlaps, are distinctly different topics with different mitigation and adaptation options. A way forward with respect to a more effective climate policy is to focus on the assessment of adaption and mitigation strategies that reduce vulnerabilities of important societal and environmental resources to both natural and human-caused climate variability and change. For example, restricting development in flood plains or in hurricane storm surge costal locations is an effective adaptation strategy, regardless of how climate changes.

In conclusion, humans are altering significantly the global climate, but in a variety of diverse ways beyond the rated effect of carbon dioxide. The CCSP assessments have been too conservative in recognizing the importance of these human climate forcings as they alter regional and global climate. These assessments have also not communicated the inability of the models to accurately forecast future regional climate on multi-decadal time scales since these other first-order human climate forcings are excluded. The forecasts, therefore, did not provide skill in quantifying the impact of different mitigation strategies on the actual climate response that would occur as a result of policy intervention with respect to only CO_2. Thank you.

[The prepared statement of Mr. Pielke follows:]

"A Broader View of the Role of Humans in the Climate System is Required In the Assessment of Costs and Benefits of Effective Climate Policy"

Written Testimony by Dr. Roger A. Pielke Sr.

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Professor Emeritus, Colorado State University, Fort Collins, CO

For the Subcommittee on Energy and Air Quality

of the Committee on Energy and Commerce

Hearing "Climate Change: Costs of Inaction" – Honorable Rick Boucher, Chairman

June 26, 2008

Summary

The human addition of CO_2 into the atmosphere is a first-order climate forcing. We need an effective policy to limit the atmospheric concentration of this gas. However, humans are significantly altering the climate system in a diverse range of ways in addition to CO_2. The information that I am presenting will assist in properly placing CO_2 policies into the broader context of climate policy.

Climate is much more than just long term weather statistics but includes all physical, chemical and biological components of the atmosphere, oceans, land surface and glacier covered areas. In 2005, the National Research Council published a report "Radiative forcing of climate change: Expanding the concept and addressing uncertainties" that documented that a human disturbance of any component of the climate system, necessarily alters other aspects of the climate.

1. Introduction

The role of humans within the climate system must be one of the following three possibilities

- **The human influence is minimal and natural variations dominate climate variations on all time scaled;**
- **While natural variations are important, the human influence is significant and involves a diverse range of first-order climate forcings, including, but not limited to the human input of CO_2;**
- **The human influence is dominated by the emissions into the atmosphere of greenhouse gases, particularly carbon dioxide**

My testimony presents evidence that the correct scientific conclusion is that

The human influence on climate is significant and involves a diverse range of first-order climate forcings, including, but not limited to the human input of CO_2.

2. Conclusions of the National Research Council – Human Climate Forcings Are More Than Just The Radiative Forcing of the Well-mixed Greenhouse Gases

In 2005, the National Research Council published the report:

National Research Council, 2005: Radiative forcing of climate change: Expanding the concept and addressing uncertainties. Committee on Radiative Forcing Effects on Climate Change, Climate Research Committee, Board on Atmospheric Sciences and

Climate, Division on Earth and Life Studies, The National Academies Press, Washington, D.C., 208 pp.

Figure 1, from the 2005 National Research Council report, illustrates that a human disturbance of any component of the climate system, necessarily alters other aspects of the climate. Climate is much more than just long-term weather statistics but includes all physical, chemical, and biological components of the atmosphere, oceans, land surface, and glacier-covered areas.

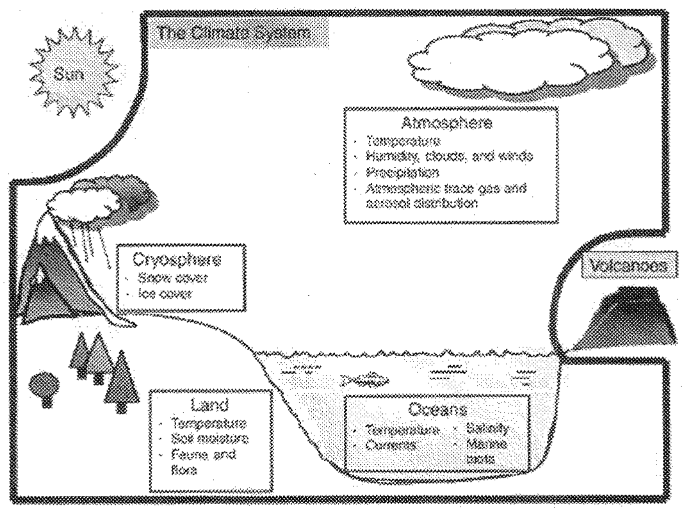

FIGURE 1: The climate system, consisting of the atmosphere, oceans, land, and cryosphere. Important state variables for each sphere of the climate system are listed in the boxes. For the purposes of this report, the Sun, volcanic emissions, and human-caused emissions of greenhouse gases and changes to the land surface are considered external to the climate system [from NRC, 2005]

The 2005 National Research Council Report concluded that the

- *"global mean surface temperature response [offers] little information on regional climate change or precipitation"*

- *"Regional variations in radiative forcing may have important regional and global climatic implications that are not resolved by the concept of global mean radiative forcing. Tropospheric aerosols and landscape changes have particularly heterogeneous forcings"*

and

- *Regional diabatic heating [from tropospheric aerosols and landscape changes] can... cause atmospheric teleconnections that influence regional climate thousands of kilometers away from the point of forcing"*

Humans, therefore, have a more diverse influence on the climate system than is represented by a focus on anthropogenic inputs of CO_2 into the atmosphere. Other investigators agree on the significance of regional heating on weather patterns. For example, as written in Palmer et al. (2008):

"As is well known, systematic changes in diabatic heating fields will perturb the planetary-wave structure of the atmosphere, in both the tropics and the extratropics"

and

"It will be decades before climate change projections can be fully verified."

There is substantial research that supports the conclusions from the 2005 National Research Council report that the human role in the climate system is more diverse than focusing only on the global warming effect of CO_2..

2a. the influence of human-caused aerosols on regional (and global) radiative heating [e.g., Ramanathan et al. 2007, Ramanathan and Carmichael 2008; Chung and Ramanathan 2003; Matsui and Pielke Sr. 2006; Niyogi et al. 2004; Rosenfeld 2006]

The presence of aerosols in the atmosphere from such human activities as fossil fuel combustion, burning of pastures and forests, and dust from degraded landscapes alters the amount of sunlight reflected back into space, and the absorption of heat within the atmosphere and at the surface. This changes the regional and global average radiative heating and cooling.

The regional heating that results from these human climate forcings produces temperature increases or decreases in the layer-averaged regional troposphere. This necessarily alters the regional pressure fields and thus the wind pattern. This pressure and wind pattern then affects the pressure and wind patterns at large distances from the region of the forcing which we refer to as teleconnections. Even surface variations such in ocean color produce such teleconnections in a general circulation model (e.g., see Shell et al. 2003).

In Matsui and Pielke Sr. (2006), it was found from observations of the spatial distribution of aerosols in the atmosphere in the lower latitudes, that the aerosol effect on atmospheric circulations, as a result of their alteration in the heating of regions of the atmosphere, is 60 times greater than due to the heating effect of the human addition of well-mixed greenhouse gases.

2b. The effect of aerosols on cloud and precipitation processes [e.g., Andreae and Rosenfeld, 2008; Rosenfeld et al. 2006, 2007; Shepherd 2006]

The presence of aerosols within the atmosphere alters cloud processes including precipitation. Among their effects, as summarized in Table 2-2 in the 2005 National Research Council report, are alterations in the lifetime of clouds, the ability of clouds to rain or snow, and the height in the atmosphere at which freezing of cloud droplets occur.

The effect of this human disturbance of the climate system extends almost worldwide. As reported in Andreae and Rosenfeld (2008), *"Model calculations and observations in remote continental regions consistently suggest that [aerosol] concentrations over the pristine continents were similar to those now prevailing over the remote oceans, suggesting that human activities have modified cloud microphysics more than what is reflected in conventional wisdom."*

2c. The influence of aerosol deposition on climate [e.g. see Biello 2007; Strack et al. 2007; Flanner et al. 2007; Myhre et al. 2005; Lamarque et al. 2005; Galloway et al. 2004; Holland et al. 2005]

The depositing of aerosols at the surface alters the reflection of sunlight back into the atmosphere, as well as alters the growth of plants. In the Arctic, for example, Biello (2007) concludes that

".... on snow—even at concentrations below five parts per billion—such dark carbon triggers melting, and may be responsible for as much as 94 percent of Arctic warming".

Increases in the deposition of nitrogen are also a major climate forcing, and are expected to increase during the current century. This deposition has altered the functioning of soil, terrestrial vegetation, and aquatic ecosystems worldwide. Galloway et al. (2004) document that human activities increasingly dominate the nitrogen budget at the global scale and that fixed forms of nitrogen are accumulating in most environmental reservoirs. Lamarque et al. (2005) conclude that

"In 2100 the nitrogen deposition changes from changes in the climate account for much less than the changes from increased nitrogen emissions."

The added nitrogen changes plant growth, and thus the reflection of sunlight from the surface, as well as the amount of vegetation available to transpire water vapor into the atmosphere.

2d. The effect of land cover/ land use on climate [e.g. Feddema et al. 2005; Salmun and Molod 2006; Marland et al. 2003; Avissar and Werth, 2005; Kleidon 2006; Mahmood et al. 2006a; Friedlingstein et al. 2001; Cox et al. 2000; Pielke 2001, 2005; Cotton and Pielke, 2007; Kabat et al. 2004; NASA, 2002, 2005]

Land-cover and land-use variations and change alter climate by changing the surface reflection of solar radiation into space, as well as the amount of heat that is transferred into the atmosphere in the form of water vapor and sensible heat. As reported in Pielke (2001)

"The net effect of deliberate landscape change such as afforestation may actually result in a radiative warming effect even though CO_2 *is extracted from the atmosphere by the plants. This occurs if the resulting surface albedo is less than for the original landscape and due to the added water vapor that is transpired into the atmosphere from the vegetation."*

Figure 2 shows that changing the current landscape (top) back to the natural landscape (bottom) in an atmospheric model for the same large-scale weather features results in a drastic alteration of the weather in the Texas and Oklahoma panhandle from a severe thunderstorm (which was observed) to just a shallow line of cumulus clouds. Figure 3 and 4 illustrate the drastic changes in landscape due to human management in Florida and in the eastern United States.

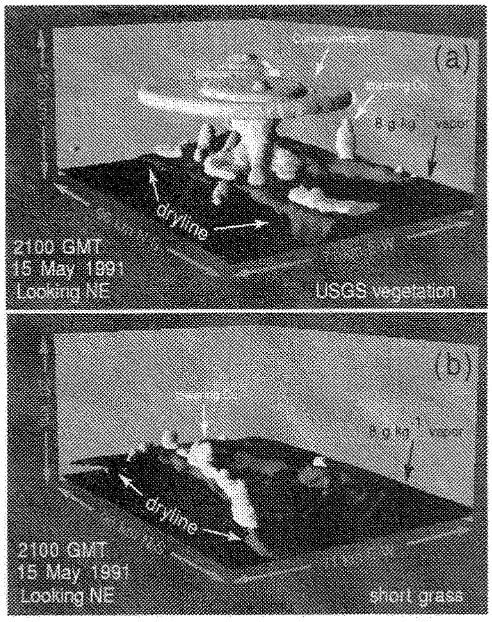

Figure 2: **From: Pielke, R.A., T.J. Lee, J.H. Copeland, J.L. Eastman, C.L. Ziegler, and C.A. Finley, 1997: Use of USGS-provided data to improve weather and climate simulations.** ***Ecological Applications,*** **7, 3-21.**

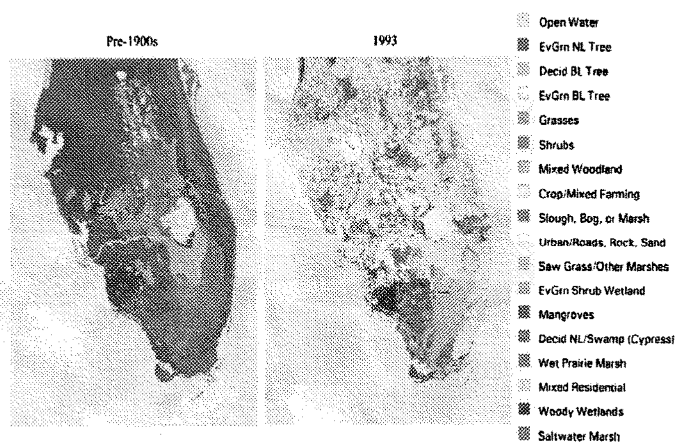

Figure 3: The observed landscape change in the 20th century for central and south Florida (from Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land cover change on warm season sensible weather and sea-breeze convection over the Florida peninsula. ***Mon. Wea Rev.,*** **132, 28-52.)**

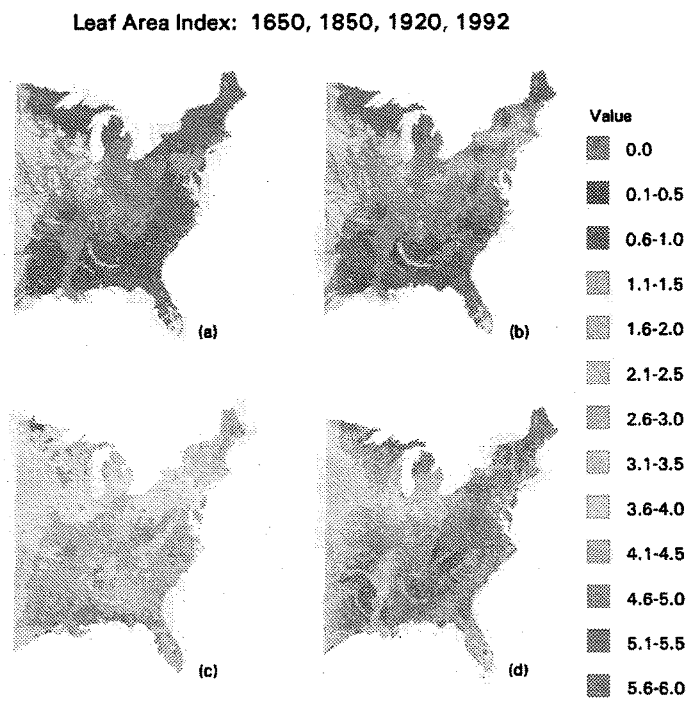

Figure 4: Distributions of average peak-season leaf area index (LAI) estimated for (a) 1650, (b) 1850, (c) 1920, and (d) 1992 time slices. With the exception of urban centers and certain degraded lands, average peak LAI for typical 10-km cells varied by 20% to 30%, variation comparable to differences among published field measurements within the same type of land cover From Steyaert and Knox (2008).

This effect extends worldwide, as demonstrated, for example, in Feddema et al. (2005) where they conclude that with respect to future land use change

"Agricultural expansion .... results in significant additional warming over the Amazon and cooling of the upper air column and nearby oceans. These and other influences on the Hadley and monsoon circulations affect extratropical climates."

In a NASA article [NASA, 2005 Gordon Bonan of NCAR stated

"Nobody experiences the effect of a half a degree increase in global mean temperature," Bonan says. "What we experience are the changes in the climate in the place where we live, and those changes might be large. Land cover change is as big an influence on regional and local climate and weather as doubled atmospheric carbon dioxide—perhaps even bigger."

2e. The biogeochemical effect of added atmospheric CO_2 [e.g., Pielke 2001; Pielke et al. 2002; Cox et al. 2000; Eastman et al. 2001; Friedlingstein et al. 2001; Cramer et al. 2001].

The addition of CO_2 into the atmosphere alters plant carbon assimilation and therefore the amount of water vapor transpired into the atmosphere. Plant growth is also altered. Cox et al. (2000) and Friedlingstein et al. (2001) conclude that the plant response to added CO_2 would amplify the warming from the radiative effect of increased CO_2, although they obtain quite different regional effects. Eastman et al. (2001) found a decrease in maximum temperatures and an increase in nighttime minimum temperatures as a result of the biogeochemical effect of doubled CO_2 in the grasslands of the Great Plains, while no significant effect resulted from the radiative changes from the added CO_2.

The research documents a first-order climate effect but its regional consequences are not well understood. Cramer et al. (2001) conclude that

"the magnitude of possible biospheric influences on the carbon balance requires that this factor is taken into account for future scenarios of atmospheric CO_2 and climate change."

The conclusion is that humans are significantly altering global and regional climates in a variety of diverse ways beyond the radiative effect of carbon dioxide is, therefore, supported by a substantial peer-reviewed literature. The assessments of costs and benefits of particular mitigation and adaptation policy actions that are intended to influence climate must include all of these diverse climate forcings.

3. Weather and Agricultural, Hydrologic and Other Impacts Respond to Regional Climate Forcings and Feedbacks Not a Global Average Temperature Trend

3a. Can regional scale climate be predicted decades into the future?

The CCSP Report "The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States" accepts model predictions and presents them as skillful predictions by the agricultural, land resources, water resources, and biodiversity impacts communities. The main focus of this assessment is the next 25-50 years. The report claims that

> *"the climate change that will occur during this period is relatively well understood. Much of this change will be caused by greenhouse gas emissions that have already happened."*

However, as shown in Section 2, the regional climate is influenced by a variety of human climate forcings besides CO_2. The global models must include all of the first-order human climate forcings as a necessary condition for skillful predictions.

As the 2007 IPCC report admitted, however, even in the context of the global average top of the atmosphere radiative forcing, they do not have all of the first-order climate forcings. They write in the caption to Figure SPM.2 with respect to the global average radiative forcings that.

> *Additional forcing factors not included here are considered to have a very low LOSU……"* [LOSU means "level of scientific understanding"]

There is no way that a skillful forecast of global and regional decades into the future can be made if all of the first-order climate forcings are not included.

3b. Can climate model predicted multi-decadal regional scale climate variations and change be attributed to specific human climate forcings?

Since all first-order human climate forcings are not included, as presented in Section 2, the attribution of specific climate forcings to a regional response is not yet scientifically robust.

With respect to assessing climate model skill, there have been recent studies on this issue. For example, as reported in Gleckler et al. (2008),

"Unlike numerical weather prediction, there is currently no widely accepted suite of metrics for evaluating climate model performance."

One of the lead authors of the 2007 IPCC report, Kevin Trenberth, although otherwise a strong proponent of the global model predictions, stated in a candid admission [Trenberth 2007] that

"In fact there are no predictions by IPCC at all. And there never have been.... None of the models used by IPCC are initialized to the observed state and none of the climate states in the models correspond even remotely to the current observed climate.... I postulate that regional climate change is impossible to deal with properly unless the models are initialized........the science is not done because we do not have reliable or regional predictions of climate."

There are even serious issues with the data that is used to validate the model predictions as well as to monitor long-term climate. For example, there are uncertainties and biases in the temperature data used to validate the model results and to assess multi-decadal temperature trends.

The land surface temperature data record is an integral component of the CCSP reports (e.g., CCSP 2006; 2008a,b). However, as one example of a data issue, the global average surface temperature trends that have been used to validate the global climate model multi-decadal predictions have been shown to have unresolved issues as discussed in a range of peer-reviewed papers [e.g. Pielke et al. 2007a,b; Walters et al. 2007; Mahmood et al. 2006b; Hale et al. 2006; Pielke and Matsui 2005; Davey and Pielke 2005].

Based on this research, for example, we found a conservative estimate of the warm bias resulting from measuring the temperature near the ground of around 0.21°C per decade (with the nighttime minimum temperature contributing a large part of this bias). Since land covers about 29% of the Earth's surface, the warm bias due to this influence explains about 30% of the IPCC estimate of global warming. In other words, consideration of the bias in temperature would reduce the IPCC trend to about 0.14°C per decade; still a warming, but not as large as indicated by the IPCC.

The message from such research is that the use of this data in the CCSP assessments will provide an erroneous overstatement of warming in the United States. Since the model predictions in the CCSP reports require this data for their impact assessments, the confidence that is placed on their use for such assessments is misplaced.

The stations used to collect temperature data are also often inappropriately located, as documented for many of the US historical climate reference network sites by Anthony Watts [see http://gallery.surfacestations.org/main.php?g2_itemId=20]. Several photographs from these sites illustrate the major shortcoming with using them in the construction of a global average surface temperature trend [see Figures 5 and 6].

The immediate environment around these sites is also changing over time as vegetation grows or is removed, air conditioners are added, buildings are relocated, etc. This poor siting introduce a substantial uncertainty in assessing extreme temperatures and temperature trends.

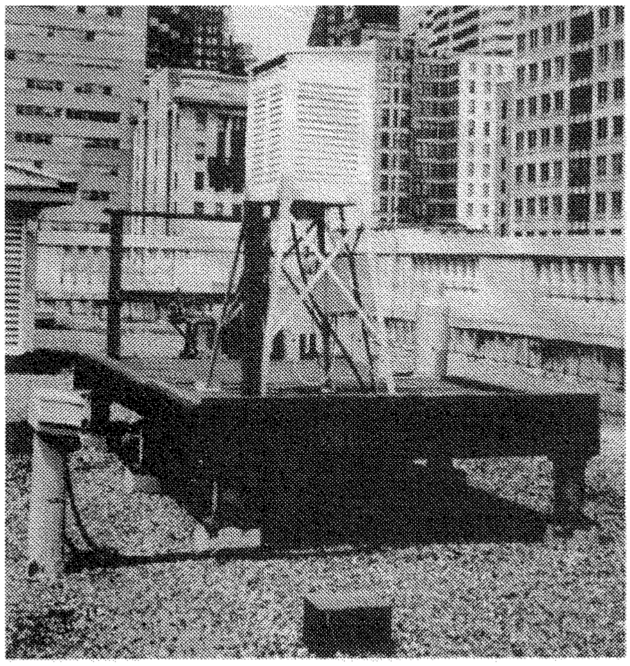

Figure 5: Location of measurement site used in long-term temperature trend assessments from Baltimore, Maryland. [http://gallery.surfacestations.org/main.php?g2_itemId=3174]

3c. Can climate model predicted multi-decadal regional scale climate variations and change be used for impacts assessments?

In order to use multi-decadal climate model predictions for accurate impacts assessments, they must have regional and local skill. However, as presented in Section 2, the models do not have this level of skill.

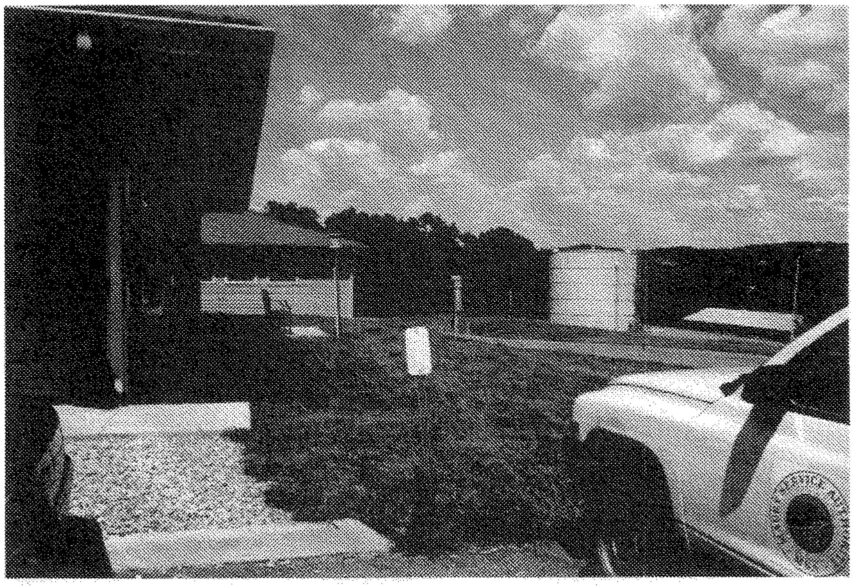

Figure 6: - Location of measurement site used in long-term temperature trend assessments at Lexington, Virginia [from http://gallery.surfacestations.org/main.php?g2_itemId=16000]

The spatial patterns of drought and of sea surface temperature anomalies in Figures 7 and 8 illustrate that regional scale information is needed. However, the global models do not yet have skill at downscaling to regional and local scales, and thus are unable to provide robust information on this spatial scale to the impacts communities. This limitation has been documented in several papers; e.g. Castro et al, 2005; 2007; Lo et al. 2008; Rockel et al. 2008)

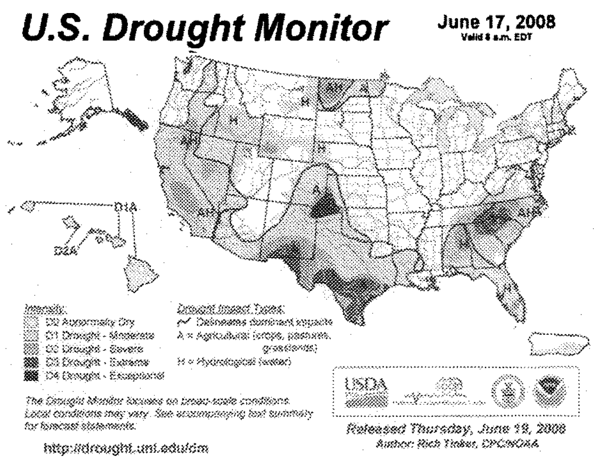

Figure 7: Drought conditions across the United States [from http://drought.unl.edu/dm/monitor.html].

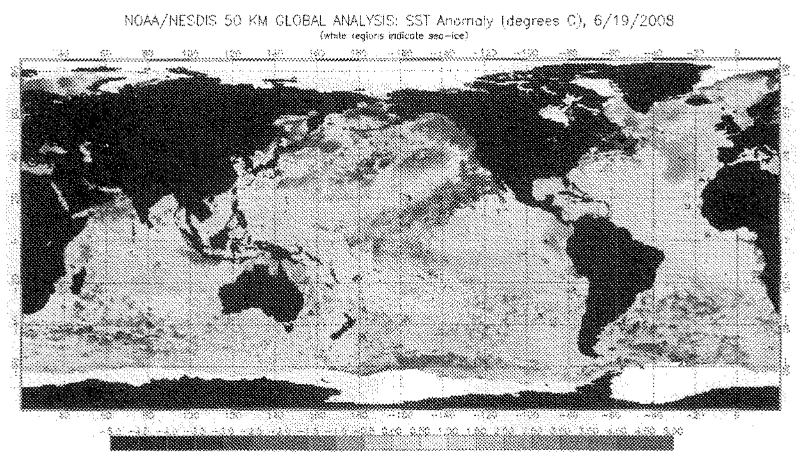

Figure 6: Global sea surface anomalies for June 19 2008 [from http://www.osdpd.noaa.gov/PSB/EPS/SST/data/anomnight.6.19.2008.gif]

In the Castro et al. (2007) paper it was concluded that

> *"In order for RCMs [regional climate model using information from a global climate model [GCM] to be successful in a seasonal weather prediction mode for the summer season, it is required that the GCM provide a reasonable representation of the teleconnections and have a climatology that is comparable to a global atmospheric reanalysis."*

Accurate seasonal regional prediction is a necessary requirement for multi-decadal climate predictions. The multi-decadal global models have not demonstrated skill at predicting on the seasonal scale.

As written in Lo et al. (2008)

> *"Regional climate simulations that rely on those predictions for LBCs and nudging are thus dominated by the global model information."*

Therefore, if the global models do not have all of the first-order human climate forcings, they cannot skillfully predict regional and local impacts.

4. Illustration of the Absence of Recognition in the CCSP Report of the Diversity of Human Climate Forcings

The neglect of the 2005 National Research Council report recommendation to broaden the assessment of the human role within the climate system was ignored in the WG1 report by the 2007 IPCC. This is illustrated for two chapters in the Appendix to this testimony.

The CCSP reports similarly ignore relevant peer-reviewed research [see Pielke, 2005 for an explanation of the conflict of interest involved with these assessments]. For example, in CCSP (2008) model predictions are accepted as robust and presented as skillful predictions by the agricultural, land resources, water resources, and biodiversity impacts communities. The report, in the CCSP Executive Summary, writes that

"our main focus is on the recent past and the nearer-term future – the next 25 to 50 years. This period is within the planning horizon of many natural resources managers. Furthermore, the climate change that will occur during this period is relatively well understood. Much of this change will be caused by greenhouse gas emissions that have already happened. It is thus partially independent of current or planned emissions control measures and the large scenario uncertainty that affects longer-term projections".

They further write that

"The IPCC AR4 projects that the global average temperature will rise another 1.1 to 5.4°C by 2100, depending on how much the atmospheric concentrations of greenhouse gases increase during this time."

Clearly, the impacts of climate change on agriculture, land resources, water resources, and biodiversity in the United States are based on model results whose main human driver is the addition of greenhouse gases into the atmosphere through human activity. Ignored in preparing these assessments are the role of all of the human climate forcings that are presented in Section 2 of this testimony.

5. Conclusions

Thus, climate policy that is designed to mitigate the human impact on regional climate by focusing only on the emissions of CO_2 is seriously incomplete unless these other first-order human climate forcings are included, or complementary policies for these other human climate forcings are developed. Moreover, it is important to recognize that climate policy and energy policy, while having overlaps, are distinctly different topics with different mitigation and adaptation options.

A way forward with respect to a more effective climate policy is to focus on the assessment of adaptation and mitigation strategies that reduce vulnerability of important societal and environmental resources to both natural and human caused climate variability and change. For example, restricting development in flood plains or in hurricane storm surge coastal locations is an effective adaptation strategy regardless of how climate changes.

This approach has been proposed in Kabat et al. (2004) and Pielke (2004) and summarized in Pielke (2004) where it is stated,

"The framework for vulnerability assessments .... is place-based and has a bottom-up perspective, in contrast to the GCM-focus [multi-decadal global model predictions] which is a top-down approach from a global perspective The vulnerability focus is on the resource of interest – [e.g.] water resources .... The challenge is to use resource specific models and observations to determine thresholds at which negative effects occur associated with the resource. Changes in the climate (represented therein by weather and land surface dynamics) represent only one threat to the resource; the climate itself may also be significantly altered by changes in the resource, and there are multiple, nonlinear interactions between the forcings... "

In conclusion, humans are significantly altering the global climate, but in a variety of diverse ways beyond the radiative effect of carbon dioxide. The CCSP assessments have been too conservative in recognizing the importance of these human climate forcings as they alter regional and global climate. These assessments have also not communicated the inability of the models to accurately forecast future regional climate on multi-decadal time scales since these other first-order human climate forcings are excluded. The forecasts, therefore, do not provide skill in quantifying the impact of different mitigation strategies on the actual climate response that would occur as a result of policy intervention with respect to only CO_2.

APPENDIX: The following is from the website Climate Science [http://climatesci.org/]; In the text below, when "Climate Science" is referred to, this refers to this website.

Documentation of IPCC WG1 Bias by Roger A. Pielke Sr. and Dallas Staley - Part I

Filed under: Climate Science Misconceptions, Climate Science Reporting — Roger Pielke Sr. @ 7:00 am

The 2007 Intergovernmental Panel on Climate Change (IPCC) Reports have the following stated goals:

"A comprehensive and rigourous picture of the global present state of knowledge of climate change"

and

"The Intergovernmental Panel on Climate Change (IPCC) has been established by WMO and UNEP to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation."

However, the IPCC WG 1 Chapter 3 report failed in this goal.

This weblog illustrates this defect using the example of their assessment of the multi-decadal land near-surface temperature trend data, where peer reviewed papers that conflicted with the robustness of the surface air temperature trends are ignored. Later Climate Science weblogs will document this issue with other climate issues.

Readers of Climate Science are invited to present other important peer reviewed papers that were available to the IPCC that were ignored in their assessment as further evidence to document IPCC bias.

To evaluate the IPCC's claim to be comprehensive, we cross-compared IPCC WG1 references on near-surface air temperature trends with the peer-reviewed citations that have been given in Climate Science. We selected only papers that appeared before about May 2006 so they were readily available to the IPCC Lead authors.

The comparison follows where the bold faced citations are in the IPCC WG1 Report:

I. ISSUES WITH THE ROBUSTNESS OF THE IPCC CONFIDENCE IN THE SURFACE TEMPERATURE RECORD

Chase, T.N., R.A. Pielke Sr., J.A. Knaff, T.G.F. Kittel, and J.L. Eastman, 2000: A comparison of regional trends in 1979-1997 depth-averaged tropospheric temperatures. Int. J. Climatology, 20, 503-518.

Davey, C.A., and R.A. Pielke Sr., 2005: Microclimate exposures of surface-based weather stations - implications for the assessment of long-term temperature trends. Bull. Amer. Meteor. Soc., Vol. 86, No. 4, 497–504.

Davey, C.A., R.A. Pielke Sr., and K.P. Gallo, 2006: Differences between near-surface equivalent temperature and temperature trends for the eastern United States - Equivalent temperature as an alternative measure of heat content. Global and Planetary Change, 54, 19–32.

de Laat, A.T.J. and A.N. Maurellis, 2006: Evidence for influence of anthropogenic surface processes on lower tropospheric and surface temperature trends. International Journal of Climatology, 26, 897-913.

González, J. E., J. C. Luvall, D. Rickman, D. E. Comarazamy, A. J. Picón, E. W. Harmsen, H. Parsiani, N. Ramírez, R. Vázquez, R. Williams, R. B. Waide, and C. A. Tepley, 2005: Urban heat islands developing in coastal tropical cities. Eos Trans. AGU, 86(42), 397.

Hale, R.C., K.P. Gallo, T.W. Owen, and T.R. Loveland, 2006: Land use/land cover change effects on temperature trends at U.S. Climate Normals Stations. Geophys. Res. Lett., 33, doi:10.1029/2006GL026358.

Hanamean, J.R. Jr., R.A. Pielke Sr., C.L. Castro, D.S. Ojima, B.C. Reed, and Z. Gao, 2003: Vegetation impacts on maximum and minimum temperatures in northeast Colorado. Meteorological Applications, 10, 203-215.

Hansen, J., R. Ruedy, J. Glascoe, and Mki. Sato, 1999: GISS analysis of surface temperature change. J. Geophys. Res. 104, 30997-31022, doi:10.1029/1999JD900835.

Hansen, J.E., R. Ruedy, Mki. Sato, M. Imhoff, W. Lawrence, D. Easterling, T. Peterson, and T. Karl, 2001: A closer look at United States and global surface temperature change. **J. Geophys. Res. 106, 23947-23963, doi:10.1029/2001JD000354.**

Hansen, J., L. Nazarenko, R. Ruedy, Mki. Sato, J. Willis, A. Del Genio, D. Koch, A. Lacis, K. Lo, S. Menon, T. Novakov, Ju. Perlwitz, G. Russell, G.A. Schmidt, and N.

Tausnev, 2005: Earth's energy imbalance: Confirmation and implications. Science 308, 1431-1435, doi:10.1126/science.1110252.

Hansen, J., Mki. Sato, R. Ruedy, L. Nazarenko, A. Lacis, G.A. Schmidt, G. Russell, I. Aleinov, M. Bauer, S. Bauer, N. Bell, B. Cairns, V. Canuto, M. Chandler, Y. Cheng, A. Del Genio, G. Faluvegi, E. Fleming, A. Friend, T. Hall, C. Jackman, M. Kelley, N. Kiang, D. Koch, J. Lean, J. Lerner, K. Lo, S. Menon, R. Miller, P. Minnis, T. Novakov, V. Oinas, Ja. Perlwitz, Ju. Perlwitz, D. Rind, A. Romanou, D. Shindell, P. Stone, S. Sun, N. Tausnev, D. Thresher, B. Wielicki, T. Wong, M. Yao, and S. Zhang 2005: Efficacy of climate forcings. J. Geophys. Res. 110, D18104, doi:10.1029/2005JD005776.

Hansen, J., M. Sato, R. Ruedy, K. Lo, D.W. Lea, and M. Medina-Elizade, 2006: Global temperature change. PNAS, 103, 14288 - 14293.

He, J. F., J. Y. Liu, D. F. Zhuang, W. Zhang, and M. L. Liu 2007: Assessing the effect of land use/land cover change on the change of urban heat island intensity Theor. Appl. Climatol., DOI 10.1007/s00704-006-0273-1

Holder, C., R. Boyles, A. Syed, D. Niyogi, and S. Raman, 2006: Comparison of Collocated Automated (NCECONet) and Manual (COOP) Climate Observations in North Carolina. J. Atmos. Oceanic Technol., 23, 671–682.

Huang Y., R. E. Dickinson and W. L. Chameides, 2006: Impact of aerosol indirect effect on surface temperature over East Asia. **Proc. Natl. Acad. Sci., 103, 4371-4376, doi: 10.1073/pnas.0504428103.**

Hubbard, K.G., and X. Lin, 2006: Reexamination of instrument change effects in the U.S. Historical Climatology Network. Geophys. Res. Lett., 33, L15710, doi:10.1029/2006GL027069.

Jones, P.D., and A. Moberg. 2003: Hemispheric and large-scale surface air temperature variations: An extensive revision and an update to 2001. J. Climate 16, 206-223.

Kalnay E., and M. Cai, 2003a: Impact of urbanization and land-use change on climate. Nature, 423, 528-531.

Kalnay, E. and M. Cai, 2003b: Impact of urbanization and land-use change on climate - Corrigenda. Nature, 425, 102.

Kalnay, E., M. Cai, H. Li, and J. Tobin, 2006: Estimation of the impact of land-surface forcings on temperature trends in eastern United States J. Geophys. Res., Vol. 111, No. D6, D06106.

Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray, Eds., 2006: Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences. **A Report by the Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC.**

Lim, Y.K., M. Cai, E. Kalnay, and L. Zhou, 2005: Observational evidence of sensitivity of surface climate changes to land types and urbanization. Geophys. Res. Lett., Vol. 32, No. 22, L2271210.1029/2005GL024267.

Mahmood, R., S.A. Foster, and D. Logan, 2006: The GeoProfile metadata, exposure of instruments, and measurement bias in climatic record revisited. Int. J. Climatology, 26(8), 1091-1124.

Parker, D.E., 2004: Large-scale warming is not urban. Nature, 432, 290, doi:10.1038/432290a;

Peterson, T.C., 2003: Assessment of urban versus rural in situ surface temperatures in the contiguous United States: No difference found. J. Climate, 16, 2941–2959.

Peterson, T.C., 2006. Examination of potential biases in air temperature caused by poor station locations. Bull. Amer. Meteor. Soc., 87, 1073-1089.

Peterson, T.C. and R.S. Vose, 1997: An overview of the Global Historical Climatology Network temperature data base. Bull. Amer. Meteor. Soc., 78, 2837-2849,

Peterson, T.C., D.R. Easterling, T.R. Karl, P. Ya. Groisman, N. Nicholls, N. Plummer, S. Torok, I. Auer, R. Boehm, D. Gullett, L. Vincent, R. Heino, H. Tuomenvirta, O. Mestre, T. Szentimre, J. Salinger, E. Førland, I. Hanssen-Bauer, H. Alexandersson, P. Jones, D. Parker, 1998: Homogeneity adjustments of in situ atmospheric climate data: A review. Int. J. Climatology, 18, 1493-1517.

Robeson, S.M., 2004: Trends in time-varying percentiles of daily minimum and maximum temperature over North America. Geophys. Res. Letts., 31, L04203, doi:10.1029/2003GL019019.

Runnalls, K.E. and T.R. Oke, 2006: A technique to detect microclimatic inhomogeneities in historical records of screen-level air temperature. J. Climate, 19, 959-978

Schmidt, G.A., R. Ruedy, J.E. Hansen, I. Aleinov, N. Bell, M. Bauer, S. Bauer, B. Cairns, V. Canuto, Y. Cheng, A. Del Genio, G. Faluvegi, A.D. Friend, T.M. Hall, Y. Hu, M. Kelley, N.Y. Kiang, D. Koch, A.A. Lacis, J. Lerner, K.K. Lo, R.L. Miller, L. Nazarenko, V. Oinas, Ja. Perlwitz, Ju. Perlwitz, D. Rind, A. Romanou, G.L. Russell, Mki. Sato, D.T. Shindell, P.H. Stone, S. Sun, N. Tausnev, D. Thresher, and M.-S. Yao, 2006: Present day atmospheric simulations using GISS ModelE: Comparison to in-situ, satellite and reanalysis data. J. Climate, 19, 153-192,

Trenberth, K.E., 2004: Rural land-use change and climate. Nature, 427, 213, doi:10.1038/427213a. doi:10.1175/JCLI3612.1.

Vose, R.S., T.R. Karl, D.R. Easterling, C.N. Williams, and M.J. Menne, 2004: Impact of land-use change on climate. Nature, 427, 213-21.

Vose, R., D.R. Easterling, and B. Gleason, 2005: Maximum and minimum temperature trends for the globe: An update through 2004. Geophys. Res. Letts., 32, L23822, doi:10.1029/2005GL024379.

Vose, R.S., D.R. Easterling, T.R. Karl, and M. Helfert, 2005: Comments on "Microclimate Exposures of Surface-Based Weather Stations?. Bull. Amer. Meteor. Soc., 86, 504–506.

Zhou, L., R.E. Dickinson , Y. Tian, J. Fang , Q. Li , R.K. Kaufmann, C.J. Tucker, and R.B. Myneni, 2004: Evidence for a significant urbanization effect on climate in China. **PNAS, 101, 9540-9544.**

If the papers were neglected because they were redundant, this would be no problem. However, they are ignored specifically because they conflict with the assessment that is presented in the IPCC WG1 Report, and the Lead Authors do not agree with that perspective!

That is hardly honoring the IPCC commitment to provide

> "A comprehensive and rigourous picture of the global present state of knowledge of climate change".

Moreover, the conflict of interest that was identified in the CCSP Report "Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences" is perpetuated in the IPCC WG1 Chapter 3 Report [where the Editor of this CCSP Report, Tom Karl, is also Review Editor for the Chapter 3 of the 2007 IPCC WG1 Report].

These comments were made with respect to this CCSP Report

"The process for completing the CCSP Report excluded valid scientific perspectives under the charge of the Committee. The Editor of the Report systematically excluded a range of views on the issue of understanding and reconciling lower atmospheric temperature trends. The Executive Summary of the CCSP Report ignores critical scientific issues and makes unbalanced conclusions concerning our current understanding of temperature trends"?

"Future assessment Committees need to appoint members with a diversity of views and who do not have a significant conflict of interest with respect to their own work. Such Committees should be chaired by individuals committed to the presentation of a diversity of perspectives and unwilling to engage in strong-arm tactics to enforce a narrow perspective. Any such committee should be charged with summarizing all relevant literature, even if inconvenient, or which presents a view not held by certain members of the Committee."

The IPCC WG1 Chapter 3 Report process made the same mistakes and failed to provide an objective assessment. Indeed the selection of papers to present in the IPCC (as well as how the work of others that was cited was dismissed) had a clear conflict of interest as the following individuals cited their research prominently yet were also a Review Editor (Tom Karl), works for the Review Editor (Tom Peterson, Russ Vose, David Easterling), were Coordinating Lead Authors (Kevin Trenberth and Phil Jones), were Lead Authors (Dave Easterling and David Parker), or a Contributing Author (Russ Vose).

In fact, as stated above, the CCSP Report "Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences", with its documented bias, was chaired by the same person as the Review Editor of the IPCC WG1 Chapter 3 Report (Tom Karl)! Regardless of his professional expertise, he is still overseeing an assessment which is evaluating his own research. There cannot be a clearer conflict of interest.

The IPCC WG1 Chapter 3 Report clearly cherrypicked information on the robustness of the land near-surface air temperature to bolster their advocacy of a particular perspective on the role of humans within the climate system. As a result, policymakers and the public have been given a false (or at best an incomplete) assessment of the multi-decadal global average near-surface air temperature trends.

Documentation Of IPCC WG1 Bias by Roger A. Pielke Sr. and Dallas Staley - Part II

Filed under: Climate Science Misconceptions, Climate Science Reporting — Roger Pielke Sr. @ 7:00 am

Among the findings of the 2005 National Research Council report Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties are

I. "Determine the Importance of Regional Variation in Radiative Forcing

Regional variations in radiative forcing may have important regional and global climatic implications that are not resolved by the concept of global mean radiative forcing. Tropospheric aerosols and landscape changes have particularly heterogeneous forcings. To date, there have been only limited studies of regional radiative forcing and response. Indeed, it is not clear how best to diagnose a regional forcing and response in the observational record; regional forcings can lead to global climate responses, while global forcings can be associated with regional climate responses. Regional diabatic heating can also cause atmospheric teleconnections that influence regional climate thousands of kilometers away from the point of forcing. Improving societally relevant projections of regional climate impacts will require a better understanding of the magnitudes of regional forcings and the associated climate responses.

PRIORITY RECOMMENDATIONS:

Use climate records to investigate relationships between regional radiative forcing (e.g., land-use or aerosol changes) and climate response in the same region, other regions, and globally.

Quantify and compare climate responses from regional radiative forcings in different climate models and on different timescales (e.g., seasonal, interannual), and report results in climate change assessments.

II. Determine the Importance of Nonradiative Forcings

Several types of forcings—most notably aerosols, land-use and land-cover change, and modifications to biogeochemistry—impact the climate system in nonradiative ways, in particular by modifying the hydrological cycle and vegetation dynamics. Aerosols exert a forcing on the hydrological cycle by modifying cloud condensation nuclei, ice nuclei, precipitation efficiency, and the ratio between solar direct and diffuse radiation received. Other nonradiative forcings modify the biological components of the climate system by changing the fluxes of trace gases and heat between vegetation, soils, and the atmosphere and by modifying the amount and types of vegetation. No metrics for quantifying such nonradiative forcings have been accepted. Nonradiative forcings have eventual radiative impacts, so one option would be to quantify these radiative impacts. However, this approach may not convey appropriately the impacts of nonradiative forcings on societally relevant climate variables such as precipitation or ecosystem function. Any new metrics must also be able to characterize the regional structure in nonradiative forcing and climate response.

PRIORITY RECOMMENDATIONS:

Improve understanding and parameterizations of aerosol-cloud thermodynamic interactions and land-atmosphere interactions in climate models in order to quantify the impacts of these nonradiative forcings on both regional and global scales.

Develop improved land-use and land-cover classifications at high resolution for the past and present, as well as scenarios for the future."

Did the IPCC WG1 Statement for Policymakers adequately discuss these issues? The answer is NO. However, these topics are discussed in Chapter 7, where, for example, it is written,

"The consequences of changes in atmospheric heating from land changes at a regional scale are similar to those from ocean temperature changes such as from El Niño, potentially producing patterns of reduced or increased cloudiness and precipitation elsewhere to maintain global energy balance. Attempts have been made to find remote adjustments (e.g., Avissar and Werth, 2005). Such adjustments may occur in multiple ways, and are part of the dynamics of climate models. The locally warmer temperatures can lead to more rapid vertical decreases of atmospheric temperature so that at some level overlying temperature is lower and radiates less. The net effect of such compensations is that averages over larger areas or longer time scales commonly will give smaller estimates of change. Thus, such regional changes are better described by local and regional metrics or at larger scales by measures of change in spatial and temporal variability rather than simply in terms of a mean global quantity."

Why was not this conclusion headlined in the policy statement that was transmitted to the politicians?

Chapter 8 of the IPCC Report is much more poorly written on this subject

where while they write

> *"Evaluation of the land surface component in coupled models is severely limited by the lack of suitable observations. The terrestrial surface plays key climatic roles in influencing the partitioning of available energy between sensible and latent heat fluxes, determining whether water drains or remains available for evaporation, determining the surface albedo and whether snow melts or remains frozen, and influencing surface fluxes of carbon and momentum. Few of these can be evaluated at large spatial or long temporal scales. This section therefore evaluates those quantities for which some observational data exist"*

they fail to identify the rich peer-reviewed literature on this subject but only provide a very limited presentation on this subject in the Chapter.

Indeed, while land processes are discussed in the Report, the focus is on its role in the carbon budget and in its effect on the global average radiative forcing.

To document missing papers, as with Part I (see and see) we have cross-referenced Climate Science with the IPCC WG1 Report on just one aspect of the above two topics (regional radiative forcing and nonradiative forcing), namely the role of land use change within the climate system.

This cross-referencing is given below where a bold face means that it appeared in the IPCC Report and the Chapter in which it appears is given. The IPCC Chapters referred to below have the titles

Chapter 2 Changes in Atmospheric Constituents and in Radiative Forcing

Chapter 6 Palaeoclimate

Chapter 7 Couplings Between Changes in the Climate System and Biogeochemistry

Chapter 8 Climate Models and their Evaluation

Chapter 10 Global Climate Projections

Chapter 11 Regional Climate Projections

II. ROLE OF LAND-USE CHANGE AS A MAJOR CLIMATE FORCING

Avissar, R., and Y. Liu, 1996: Three-dimensional numerical study of shallow convective clouds and precipitation induced by land surface forcing. J. Geophys. Res., 101(D3), 7499-7518, 10.1029/95JD03031. http://www.agu.org/pubs/crossref/1996.../95JD03031.shtml

Avissar, R., and D. Werth, 2005: Global hydroclimatological teleconnections resulting from. tropical deforestation. J. Hydrometeor., 6, 134–145. *IN CHAPTER 7 & CHAPTER 11*

Brovkin, V., M. Claussen, E. Driesschaert, T. Fichefet, D. Kicklighter, M. F. Loutre, H. D. Matthews, N. Ramankutty, M. Schaeffer, and A. Sokolov, 2006: Biogeophysical effects of historical land cover changes simulated by six Earth system models of intermediate complexity. Climate Dynamics, 1-14, DOI: 10.1007/s00382-005-0092-6. *IN CHAPTER 2 & CHAPTER 8*

Cai, M., and E. Kalnay, 2004: Response to the comments by Vose et al. and Trenberth. Impact of land-use change on climate, Nature, 427, 214, doi:10.1038/427214a.

Chase, T.N., R.A. Pielke, T.G.F. Kittel, R.R. Nemani, and S.W. Running, 2000: Simulated impacts of historical land cover changes on global climate in northern winter. Climate Dynamics, 16, 93-105. ***IN CHAPTER 2 & CHAPTER 11***

Chase, T.N., R.A. Pielke, Sr., T.G.F. Kittel, M. Zhao, A.J. Pitman, S.W. Running, and R.R. Nemani, 2001: The relative climatic effects of landcover change and elevated carbon dioxide combined with aerosols: A comparison of model results and observations. J. Geophys. Res., Atmospheres, 106, 31,685 -31,691.

Claussen, M., C. Kubatzki, V. Brovkin, A. Ganopolski, P. Hoelzmann, H.-J. Pachur, 1999; Simulation of an abrupt change in Saharan vegetation in the mid-Holocene. Geophys. Res. Lett., 26(14), 2037-2040, 10.1029/1999GL900494. ***IN CHAPTER 6, CHAPTER 10 & CHAPTER 11***

Cotton, W.R. and R.A. Pielke, 2007: Human impacts on weather and climate. Cambridge University Press, 330 pp.

Cox, P. M., R. A. Betts, C. D. Jones, S. A. Spall, and I. J. Totterdell, 2000: Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. Nature, 408, 184-187. ***IN CHAPTER 7, CHAPTER 8, CHAPTER 10 & CHAPTER 11***

Cui, X., H.-F. Graf, B. Langmann, W. Chen, and R. Huang, 2006: Climate impacts of anthropogenic land use changes on the Tibetan Plateau, Global and Planetary Change, 54, 1-2, 33-56.

Eastman, J.L., M.B. Coughenour, and R.A. Pielke, 2001: The effects of CO_2 and landscape change using a coupled plant and meteorological model. Global Change Biology, 7, 797-815.

Eugster, W., W.R. Rouse, R.A. Pielke, J.P. McFadden, D.D. Baldocchi, T.G.F. Kittel, F.S. Chapin III, G.E. Liston, P.L. Vidale, E. Vaganov, and S. Chambers, 2000: Land-atmosphere energy exchange in Arctic tundra and boreal forest: available data and feedbacks to climate. Global Change Biology, 6, 84-115.

Feddema, J.J., K.W. Oleson, G.B. Bonan, L.O. Mearns, L.E. Buja, G.A. Meehl, and W.M. Washington, 2005: The importance of land-cover change in simulating future climates. Science, 310, 1674-1678. *IN CHAPTER 10*

Foley, J.A., R. DeFries, G.P. Asner, C. Barford, G. Bonan, S.R. Carpenter, F.S. Chapin, M.T. Coe, G.C. Daily, H.K. Gibbs, J.H. Helkowski, T. Holloway, E.A. Howard, C.J. Kucharik, C. Monfreda, J.A. Patz, I.C. Prentice, N. Ramankutty, and P.K. Snyder, 2005: Global consequences of land use. Science, 309, 570-574. *IN CHAPTER 11*

Friedlingstein P., L. Bopp, P. Ciais, J.-L Dufresne, L. Fairhead, H. LeTreut, P. Monfray, and J. Orr, 2001: Positive feedback between future climate change and the carbon cycle. Geophys. Res. Lett., 28, 1543-1546. *IN CHAPTER 7, CHAPTER 8, & CHAPTER 11*

Gero, A.F., A.J. Pitman, G.T. Narisma, C. Jacobson, and R.A. Pielke Sr., 2006: The impact of land cover change on storms in the Sydney Basin. Global and Planetary Change, 54, 57-78.

Gibbard, S., K. Caldeira, G. Bala, T. J. Phillips, and M. Wickett, 2005: Climate effects of global land cover change. Geophys. Res. Lett., 32, L23705, doi:10.1029/2005GL024550.

Hoffmann, W.A., and R.B. Jackson, 2000: Vegetation-climate feedbacks in the conversion of tropical savanna to grassland. J. Climate, 13, 1593–1602.

Holt, T.R., D. Niyogi, F. Chen, K. Manning, M.A. LeMone, and A. Qureshi, 2006: Effect of land–atmosphere interactions on the IHOP 24–25 May 2002 convection case. Mon. Wea. Rev., 134, 113–133.

Kleidon, A., 2006: The climate sensitivity to human appropriation of vegetation productivity and its thermodynamic characterization. Global and Planetary Change, 54, 109-127. doi:10.1016/j.gloplacha.2006.01.016

Lawton, R.O., U.S. Nair, R.A. Pielke Sr., and R.M. Welch, 2001: Climatic impact of tropical lowland deforestation on nearby montane cloud forests. Science, 294, 584-587.

Lee, E., R.S. Oliveira, T.E. Dawson, and I. Fung, 2005: Root functioning modifies seasonal climate. Proceedings of the National Academy of Sciences, 102, no. 49, 17576-17581.

Mahmood, R., S.A. Foster, T. Keeling, K.G. Hubbard, C. Carlson and R. Leeper, 2006: Impacts of irrigation on 20th century temperature in the northern Great Plains. Global and Planetary Change, 54, 1-18. doi:10.1016/j.gloplacha.2005.10.004.

Marland, G., R.A. Pielke, Sr., M. Apps, R. Avissar, R.A. Betts, K.J. Davis, P.C. Frumhoff, S.T. Jackson, L. Joyce, P. Kauppi, J. Katzenberger, K.G. MacDicken, R. Neilson, J.O. Niles, D. dutta S. Niyogi, R.J. Norby, N. Pena, N. Sampson, and Y. Xue, 2003:

The climatic impacts of land surface change and carbon management, and the implications for climate-change mitigation policy. Climate Policy, 3, 149-157. ***IN CHAPTER 11***

Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land-cover change on the Florida peninsula sea breezes and warm season sensible weather. Mon. Wea. Rev., 132, 28-52.

Marshall, C.H., R.A. Pielke Sr., and L.T. Steyaert, 2004: Has the conversion of natural wetlands to agricultural land increased the incidence and severity of damaging freezes in south Florida? Mon. Wea. Rev., 132, 2243-2258.

Millán, M. M., Mª. J. Estrela, M. J. Sanz, E. Mantilla, M. Martín, F. Pastor, R. Salvador, R. Vallejo, L. Alonso, G. Gangoiti, J.L. Ilardia, M. Navazo, A. Albizuri, B. Artiñano, P. Ciccioli, G. Kallos, R.A. Carvalho, D. Andrés, A. Hoff, J. Werhahn, G. Seufert, B, Versino, 2005: Climatic Feedbacks and Desertification: The Mediterranean model. J. Climate, 18 (5), 684-701.

Myhre, G., Y. Govaerts, J. M. Haywood, T. K. Berntsen, and A. Lattanzio, 2005: Radiative effect of surface albedo change from biomass burning. Geophys. Res. Lett., 32, L20812, doi:10.1029/2005GL022897.

Nair, U.S., R.O. Lawton, R.M. Welch, and R.A. Pielke Sr., 2003: Impact of land use on Costa Rican tropical montane cloud forests: 1. Sensitivity of cumulus cloud field characteristics to lowland deforestation. J. Geophys. Res. - Atmospheres, 108, 10.1029/2001JD001135.

National Research Council, 2005: Radiative forcing of climate change: Expanding the concept and addressing uncertainties. Committee on Radiative Forcing Effects on Climate Change, Climate Research Committee, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, The National Academies Press, Washington, D.C., 208 pp. Referenced as Jacob et al. in the IPCC; *IN CHAPTER 2*

Nemani, R.R., S.W. Running, R.A. Pielke, and T.N. Chase, 1996: Global vegetation cover changes from coarse resolution satellite data. J. Geophys. Res., 101, 7157-7162.

Niyogi, D., T. Holt, S. Zhong, P.C. Pyle, and J. Basara, 2006: Urban and land surface effects on the 30 July 2003 mesoscale convective system event observed in the southern Great Plains. J. Geophys. Res., 111, D19107, doi:10.1029/2005JD006746.

Notaro, M., Z. Liu, R. Gallimore, S.J. Vavrus, J.E. Kutzbach, I.C. Prentice, and R.L. Jacob, 2005: Simulated and observed preindustrial to modern vegetation and climate changes. J. Climate, 18, 3650–3671.

Pielke Sr., R.A., 2001: Influence of the spatial distribution of vegetation and soils on the prediction of cumulus convective rainfall. Rev. Geophys., 39, 151-177. *IN CHAPTER 7*

Pielke Sr., R.A., 2005: Land use and climate change. Science, 310, 1625-1626.

Pielke Sr., R.A., G. Marland, R.A. Betts, T.N. Chase, J.L. Eastman, J.O. Niles, D. Niyogi, and S. Running, 2002: The influence of land-use change and landscape dynamics on the climate system- relevance to climate change policy beyond the radiative effect of

greenhouse gases. Phil. Trans. A. Special Theme Issue, 360, 1705-1719. ***IN CHAPTER 2 & CHAPTER 11***

Pitman, A.J., G.T. Narisma, R.A. Pielke Sr., and N.J. Holbrook, 2004: The impact of land cover change on the climate of southwest western Australia. J. Geophys. Res., 109, D18109, doi:10.1029/2003JD004347.

Ramunkutty, N., C. Delire and P. Snyder, 2006: Feedbacks between agriculture and climate: An illustration of the potential unintended consequences of human land use activities. Global and Planetary Change, 54, 1-2, 79-93, doi:10.1016/j.gloplacha.2005.10.005

Ray, D.K., U.S. Nair, R.O. Lawton, R.M. Welch, and R.A. Pielke Sr., 2006: Impact of land use on Costa Rican tropical montane cloud forests. Sensitivity of orographic cloud formation to deforestation in the plains. J. Geophys. Res., 111, doi:10.1029/2005JD006096.

Ray, D.K., R.M. Welch, R.O. Lawton, and U.S. Nair, 2006: Dry season clouds and rainfall in northern Central America: Implications for the Mesoamerican Biological Corridor. Global and Planetary Change, 54, 150-162.

Salmun, H., and A. Molod, 2006: Progress in modeling the impact of land cover change on the global climate. Progress in Physical Geography, 30, 737–749.

Sturm, M., T. Douglas, C. Racine, and G.E. Liston, 2005: Changing snow and shrub conditions affect albedo with global implications. J. Geophys. Res., 110, G01004, doi:10.1029/2005JG000013. ***IN CHAPTER 7***

TerMaat, H.W., R.W.A. Hutjes, R. Ohba, H. Ueda, B. Bisselink and T. Bauer, 2006: Meteorological impact assessment of possible large scale irrigation in Southwest Saudi Arabia. Global and Planetary Change, 54, 183-201.

Timbal, B., and J.M. Arblaster, 2006: Land cover change as an additional forcing to explain the rainfall decline in the south west of Australia. Geophys. Res. Lett., 33, L07717, doi:10.1029/2005GL025361.

van der Molen, M.K., A.J. Dolman, M.J. Waterloo and L.A. Bruijnzeel, 2006: Climate is affected more by maritime than by continental land use change: A multiple scale analysis. Global and Planetary Change, 54, 128-149.

Werth, D., and R. Avissar, 2002: The local and global effects of Amazon deforestation. J. Geophys. Res., 107, 8087, doi:10.1029/2001JD000717

Here are several summary points from this assessment:

1. The 2005 NRC Report was only cited in one chapter (Chapter 2), and its recommendations are not considered in any of the following chapters.

2. None of the papers were cited in Chapter 9 which is entitled "Understanding and Attributing Climate Change". As documented in the papers listed above, the attribution of climate change cannot be accurately accomplished without including land surface processes, including land use change.

3. The important role of land surface processes in the IPCC chapters is presented in a sporadic fashion without the needed focused evaluation of its role, as recommended in the 2005 NRC

Report. The 2007 IPCC Report did not adequately honor the charge of the IPCC WG1 Report to provide "A comprehensive and rigourous picture of the global present state of knowledge of climate change".

Finally, if one suggests that the set of papers that were referenced in the IPCC report are a representative sample that cover the range of issues with the role of land surface processes (which Climate Science concludes is not the case), than refer us to the text in the IPCC report that addresses the issue of the importance of regional radiative and non-radiative climate forcings on the climate system. The IPCC Report fails on this much needed assessment of the role of humans in the climate system.

References

Andreae, M.O., and D. Rosenfeld, 2008: Aerosol–cloud–precipitation interactions. Part 1. The nature and sources of cloud-active aerosols. Earth System Reviews, 13-41, doi:10.1016/j.earscirev.2008.03.001

Avissar, R., and D. Werth, 2005: Global hydroclimatological teleconnections resulting from. tropical deforestation. J. Hydrometeor., 6, 134–145.

Biello, D., 2007: Impure as the Driven Snow - Smut is a bigger problem than greenhouse gases in polar meltdown. Scientific American, June 8, 2007, Available at: http://www.sciam.com/article.cfm?id=impure-as-the-driven-snow

Castro, C.L., R.A. Pielke Sr., and G. Leoncini, 2005: Dynamical downscaling: Assessment of value retained and added using the Regional Atmospheric Modeling System (RAMS). J. Geophys. Res. - Atmospheres, 110, No. D5, D05108, doi:10.1029/2004JD004721. http://climatesci.colorado.edu/publications/pdf/R-276.pdf

Castro, C.L., R.A. Pielke Sr., J. Adegoke, S.D. Schubert, and P.J. Pegion, 2007: Investigation of the summer climate of the contiguous U.S. and Mexico using the Regional Atmospheric Modeling System (RAMS). Part II: Model climate variability. J. Climate, 20, 3866-3887. http://climatesci.colorado.edu/publications/pdf/R-307.pdf

CCSP, 2006: Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences. Thomas R. Karl, Susan J. Hassol, Christopher D. Miller, and William L. Murray, editors, 2006. A Report by the Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC.

CCSP, 2008a: The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research CONVENING LEAD AUTHORS: Peter Backlund, Anthony Janetos, and David Schimel. MANAGING EDITOR: Margaret Walsh

CCSP, 2008b: *Weather and Climate Extremes in a Changing Climate*. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Thomas R. Karl, Gerald A. Meehl, Christopher D. Miller, Susan J. Hassol, Anne M. Waple, and William L. Murray (eds.)]. Department of Commerce, NOAA's National Climatic Data Center, Washington, D.C., USA, 164 pp. Available at: http://www.climatescience.gov/Library/sap/sap3-3/final-report/default.htm

Chung, C. E., and V. Ramanathan. 2003: South Asian haze forcing: Remote impacts with implications to ENSO and AO. J. Climate, 16, 1791-1806. http://ams.allenpress.com/perlserv/?request=get-abstract&doi=10.1175%2F1520-0442%282003%29016%3C1791%3ASAHFRI%3E2.0.CO%3B2

Cotton, W.R. and R.A. Pielke, 2007: Human impacts on weather and climate. Cambridge University Press, 330 pp. http://www.cambridge.org/catalogue/catalogue.asp?isbn=9780521600569

Cox, P. M., R. A. Betts, C. D. Jones, S. A. Spall, and I. J. Totterdell, 2000: Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. Nature, 408, 184-187.

Cramer, W. Alberte Bondeau, F. Ian Woodward, I. Colin Prentice, Richard A. Betts, Victor Brovkin, Peter M. Cox, Veronica Fisher, Jonathan A. Foley, Andrew D. Friend, Chris Kucharik, Mark R. Lomas, Navin Ramankutty, Stephen Sitch, Benjamin Smith, Andrew White, Christine Young-Molling, 2001: Global response of terrestrial ecosystem structure and function to CO_2 and climate change: results from six dynamic global vegetation models. Global Change Biology, 7 (4), 357–373, doi:10.1046/j.1365-2486.2001.00383.x

Davey, C.A., and R.A. Pielke Sr., 2005: Microclimate exposures of surface-based weather stations - implications for the assessment of long-term temperature trends. Bull. Amer. Meteor. Soc., Vol. 86, No. 4, 497–504. http://climatesci.colorado.edu/publications/pdf/R-274.pdf

Feddema et al. 2005: The importance of land-cover change in simulating future climates. 310, 1674-1678. http://climatesci.colorado.edu/publications/pdf/Feddema2005.pdf

Eastman, J.L., M.B. Coughenour, and R.A. Pielke, 2001: The effects of CO_2 and landscape change using a coupled plant and meteorological model. Global Change Biology, 7, 797-815. http://climatesci.colorado.edu/publications/pdf/R-229.pdf

Flanner, M. G., C. S. Zender, J. T. Randerson, and P. J. Rasch, 2007: Present-day climate forcing and response from black carbon in snow. J. Geophys. Res., 112, D11202, doi:10.1029/2006JD008003.

http://www.agu.org/pubs/crossref/2007.../2006JD008003.shtml

Freud, E., D. Rosenfeld, M.O. Andreae, A.A. Costa, and P. Artaxo, 2008: Robust relations between CCN and the vertical evolution of cloud drop size distribution in deep convective clouds. Atmos. Chem. Phys., 8, 1661-1675. http://www.atmos-chem-phys.org/8/1661/2008/acp-8-1661-2008.pdf

Friedlingstein P., L. Bopp, P. Ciais, J.-L Dufresne, L. Fairhead, H. LeTreut, P. Monfray, and J. Orr, 2001: Positive feedback between future climate change and the carbon cycle. Geophys. Res. Lett., 28, 1543-1546.

Galloway, F.J. Dentine, D.G. Capone, E.W. Boyer, R. W. Howarth, S.P. Seitzinger, G.P. Asner, C.C. Cleveland, P.A. Green, E.A. Holland, D.M. Karl, A.F. Michaels, J.H. Porter, A.R. Townsend, and C.J. Vörosmarty, 2004: Nitrogen cycles: Past, present and future. Biogeochemistry, 70, 153-226. http://www.springerlink.com/content/rqg2610786337vv8/

Gleckler, P. J., K. E. Taylor, and C. Doutriaux, 2008: Performance metrics for climate models. J. Geophys. Res., 113, D06104, doi:10.1029/ http://www.agu.org/pubs/crossref/2008/2007JD008972.shtml

Hale, R. C., K. P. Gallo, T. W. Owen, and T. R. Loveland, 2006: Land use/land cover change effects on temperature trends at U.S. Climate. Geophys. Res. Letts., 33, L11703, doi:10.1029/2006GL026358. http://www.agu.org/pubs/crossref/2006/2006GL026358.shtml

Holland, E.A., B.H. Braswell, J. Sulzman, and J.-F. Lamarque, 2005; Nitrogen deposition onto the United States and Western Europe: A synthesis of observations and models. Ecological Applications, 15, 38-57. http://www.esajournals.org/perlserv/?request=get-abstract&issn=1051-0761&volume=15&issue=1&page=38&ct=1

Kabat, P., Claussen, M., Dirmeyer, P.A., J.H.C. Gash, L. Bravo de Guenni, M. Meybeck, R.A. Pielke Sr., C.J. Vorosmarty, R.W.A. Hutjes, and S. Lutkemeier, Editors, 2004: Vegetation, water, humans and the climate: A new perspective on an interactive system. Springer, Berlin, Global Change - The IGBP Series, 566 pp

Kleidon, A., 2006: The climate sensitivity to human appropriation of vegetation productivity and its thermodynamic characterization. Global and Planetary Change, 54, 109-127. doi:10.1016/j.gloplacha.2006.01.016. http://www.bgc-jena.mpg.de/bgc-theory/uploads/Pubs/2006-GPC-HANPP.pdf

Lamarque, J.-F., et al. (2005), Assessing future nitrogen deposition and carbon cycle feedback using a multimodel approach: Analysis of nitrogen deposition, J. Geophys. Res., 110, D19303, doi: 10.1029/2005JD005825. http://www.agu.org/pubs/crossref/2005/2005JD005825.shtml

Lo, J.C.-F., Z.-L. Yang, and R.A. Pielke Sr., 2008: Assessment of three dynamical climate downscaling methods using the Weather Research and Forecasting (WRF) Model. J. Geophys. Res., 113, D09112, doi:10.1029/2007JD009216. http://climatesci.colorado.edu/publications/pdf/R-332.pdf

Mahmood, R., S.A. Foster, T. Keeling, K.G. Hubbard, C. Carlson and R. Leeper, 2006a: Impacts of irrigation on 20th century temperature in the northern Great Plains. Global and Planetary Change, 54, 1-18. doi:10.1016/j.gloplacha.2005.10.004. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VF0-4KHC39N-1&_user=10&_coverDate=11%2F30%2F2006&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=60f10bb7ae3d0899dccc89ada7f21a32

Mahmood, R., S.A. Foster, and D. Logan, 2006b: The geoprofile metadata, exposure of instruments, and measurement bias in climatic record revisited. Int. J. Climatology, 26: 1091-1124. http://www3.interscience.wiley.com/journal/112518278/abstract?CRETRY=1&SRETRY=0

Marland, G., R.A. Pielke, Sr., M. Apps, R. Avissar, R.A. Betts, K.J. Davis, P.C. Frumhoff, S.T. Jackson, L. Joyce, P. Kauppi, J. Katzenberger, K.G. MacDicken, R. Neilson, J.O. Niles, D. dutta S. Niyogi, R.J. Norby, N. Pena, N. Sampson, and Y. Xue, 2003: The climatic impacts of land surface change and carbon management, and the implications for climate-change mitigation policy. Climate Policy, 3, 149-157. http://climatesci.colorado.edu/publications/pdf/R-267.pdf

Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land cover change on warm season sensible weather and sea-breeze convection over the Florida peninsula. Mon. Wea Rev., 132, 28-52. http://climatesci.colorado.edu/publications/pdf/R-272.pdf

Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974 http://climatesci.colorado.edu/publications/pdf/R-312.pdf

Myhre, G., Y. Govaerts, J. M. Haywood, T. K. Berntsen, and A. Lattanzio, 2005: Radiative effect of surface albedo change from biomass burning. Geophys. Res. Lett., 32, L20812, doi:10.1029/2005GL022897. http://www.agu.org/pubs/crossref/2005/2005GL022897.shtml

NASA, 2002: Landcover changes may rival greenhouse gases as cause of climate change. http://www.gsfc.nasa.gov/topstory/20020926landcover.html

NASA, 2005: Deep Freeze and Sea Breeze: Changing Land and Weather in Florida. http://earthobservatory.nasa.gov/Study/DeepFreeze/

National Research Council, 2005: Radiative forcing of climate change: Expanding the concept and addressing uncertainties. Committee on Radiative Forcing Effects on Climate Change, Climate Research Committee, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, The National Academies Press, Washington, D.C., 208 pp. http://www.nap.edu/openbook.php?isbn=0309095069

Niyogi, D., H. Chang, V.K. Saxena, T .Holt, K. Alapaty, F. Booker, F. Chen, K.J. Davis, B. Holben, T. Matsui, T. Meyers, W.C. Oechel, R. A. Pielke Sr., R. Wells, K. Wilson, Y.K. Xue, 2004: Direct observations of the effects of aerosol loading on net ecosystem CO_2 exchanges over different landscapes. Geophys. Res. Letts., L20506, doi:10.1029/2004GL020915. http://climatesci.colorado.edu/publications/pdf/R-269.pdf

Palmer, T. N., F. J. Doblas-Reyes, A. Weisheimer, and M. J. Rodwell, 2008: Toward seamless prediction: Calibration of climate change projections using seasonal forecasts. Bull. Amer. Meteor. Soc., 89, 4, 459–470, DOI: 10.1175/BAMS-89-4-459. http://ams.allenpress.com/perlserv/?request=get-abstract&doi=10.1175%2FBAMS-89-4-459

Pielke Sr., R.A., 2001: Carbon sequestration — The need for an integrated climate system approach. Bull. Amer. Meteor. Soc., 82, 2021. http://climatesci.colorado.edu/publications/pdf/R-248.pdf

Pielke, R.A. Sr., 2004: Discussion Forum: A broader perspective on climate change is needed. IGBP Newsletter, 59, 16-19. http://climatesci.colorado.edu/publications/pdf/NR-139.pdf

Pielke Sr., R.A., 2005: Land use and climate change. Science, 310, 1625-1626 Pielke Sr., Roger A., 2005: Public Comment on CCSP Report "Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences". 88 pp including appendices. http://climatesci.colorado.edu/publications/pdf/NR-143.pdf

Pielke Sr., R.A., and T. Matsui, 2005: Should light wind and windy nights have the same temperature trends at individual levels even if the boundary layer averaged heat content change is the same? Geophys. Res. Letts., 32, No. 21, L21813, 10.1029/2005GL024407. http://climatesci.colorado.edu/publications/pdf/R-302.pdf

Pielke Sr., R.A., G. Marland, R.A. Betts, T.N. Chase, J.L. Eastman, J.O. Niles, D. Niyogi, and S. Running, 2002: The influence of land-use change and landscape dynamics on the climate system- relevance to climate change policy beyond the radiative effect of greenhouse gases. Phil. Trans. A. Special Theme Issue, 360, 1705-1719. http://climatesci.colorado.edu/publications/pdf/R-258.pdf

Pielke, R.A., T.J. Lee, J.H. Copeland, J.L. Eastman, C.L. Ziegler, and C.A. Finley, 1997: Use of USGS-provided data to improve weather and climate simulations. Ecological Applications, 7, 3-21. http://climatesci.colorado.edu/publications/pdf/R-175.pdf

Pielke Sr., R.A. J. Nielsen-Gammon, C. Davey, J. Angel, O. Bliss, N. Doesken, M. Cai., S. Fall, D. Niyogi, K. Gallo, R. Hale, K.G. Hubbard, X. Lin, H. Li, and S. Raman, 2007: Documentation of uncertainties and biases associated with surface temperature measurement sites for climate change assessment. Bull. Amer. Meteor. Soc., 88:6, 913-928. http://climatesci.colorado.edu/publications/pdf/R-318.pdf

Pielke Sr., R.A., C. Davey, D. Niyogi, S. Fall, J. Steinweg-Woods, K. Hubbard, X. Lin, M. Cai, Y.-K. Lim, H. Li, J. Nielsen-Gammon, K. Gallo, R. Hale, R. Mahmood, S. Foster, R.T. McNider, and P. Blanken, 2007: Unresolved issues with the assessment of multi-decadal global land surface temperature trends. J. Geophys. Res., 112, D24S08, doi:10.1029/2006JD008229. http://climatesci.colorado.edu/publications/pdf/R-321.pdf

Ramanathan, V., and G. Carmichael, 2008: Global and regional climate changes due to black carbon. Nature Geosciences, 221-227, doi:10.1038/ngeo156.

Ramanathan, V. et al., 2007: Atmospheric brown clouds: Hemispherical and regional variations in long-range transport, absorption, and radiative forcing. J. Geophys. Res., 112, D22S21, doi:10.1029/2006JD008124.

http://www.agu.org/pubs/crossref/2007/2006JD008124.shtml

Rockel, B., C.L. Castro, R.A. Pielke Sr., H. von Storch, and G. Leoncini, 2008: Dynamical downscaling: Assessment of model system dependent retained and added variability for two different regional climate models. J. Geophys. Res., submitted. http://climatesci.colorado.edu/publications/pdf/R-325.pdf

Rosenfeld D., 2006: Aerosol-cloud interactions control of Earth radiation and latent heat release. *Space Science Reviews*. Springer, 6 December 2006. 9p., DOI: 10.1007/s11214-006-9053-6. http://earth.huji.ac.il/data/pics/Space_Science_Reviews_Rosenfeld06.pdf

Rosenfeld, D., J. Dai, X. Yu, Z. Yao, X. Xu, X. Yang, and C. Du, 2007: Inverse relations between amounts of air pollution and orographic precipitation. Science, 315, 9 March 2007, 1396-1398. http://earth.huji.ac.il/data/pics/Science07_China.pdf

Salmun, H., and A. Molod, 2006: Progress in modeling the impact of land cover change on the global climate. Progress in Physical Geography, 30, 737–749. http://ppg.sagepub.com/cgi/reprint/30/6/737

Shell, K. M., R. Frouin, S. Nakamoto, and R. C. J. Somerville, 2003: Atmospheric response to solar radiation absorbed by phytoplankton. J. Geophys. Res., 108(D15), 4445, doi:10.1029/2003JD003440.

http://www.agu.org/pubs/crossref/2003/2003JD003440.shtml

Shepherd, J. M., 2006: Evidence of urban-induced precipitation variability in arid climate regions, *J. Arid. Env.*, **67**, 607-628.

http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6WH9-4K1HDTV-1&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=988b352a250dbed7ab27f26416dc86eb

Steyaert, L.T., and R.G. Knox, 2008: Reconstructed historical land cover and biophysical parameters for studies of land-atmosphere interactions within the eastern United States, J. Geophys. Res., 113, D02101, doi:10.1029/2006JD008277. http://www.agu.org/pubs/crossref/2008/2006JD008277.shtml

Strack, J., R.A. Pielke Sr., and G. Liston, 2007: Arctic tundra shrub invasion and soot deposition: Consequences for spring snowmelt and near-surface air temperatures. J. Geophys. Res., 112, G04S44, doi:10.1029/2006JG000297. http://climatesci.colorado.edu/publications/pdf/R-309.pdf

Trenberth, K. 2007: Predictions of climate. Posted on Climate Feedback, The Climate Change Blog, June 4, 2007. http://blogs.nature.com/climatefeedback/2007/06/predictions_of_climate.html

Walters, J.T., R.T. McNider, X. Shi, W.B. Norris, and J.R. Christy, 2007: Positive surface temperature feedback in the stable nocturnal boundary layer. Geophys. Res. Lett., 34, L12709, doi:10.1029/2007GL029505. http://www.agu.org/pubs/crossref/2007/2007GL029505.shtml

Oral Testimony

"A Broader View of the Role of Humans in the Climate System is Required In the Assessment of Costs and Benefits Effective Climate Policy"

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For the Subcommittee on Energy and Air Quality of the Committee on Energy and Commerce – Honorable Rick Boucher, Chairman

June 26, 2008

The human addition of CO_2 into the atmosphere is a first-order climate forcing. We need an effective policy to limit the atmospheric concentration of this gas. However, humans are significantly altering the climate system in a diverse range of ways in addition to CO_2. The information that I am presenting will assist in properly placing CO_2 policies into the broader context of climate policy.

Climate is much more than just long-term weather statistics but includes all physical, chemical, and biological components of the atmosphere, oceans, land surface, and glacier-covered areas. In 2005, the National Research Council published a report "Radiative forcing of climate change: Expanding the concept and addressing uncertainties" that documented that a human disturbance of any component of the climate system, necessarily alters other aspects of the climate.

The role of humans within the climate system must, therefore, be one of the following three possibilities

- **The human influence is minimal and natural variations dominate climate variations on all time scales;**
- **While natural variations are important, the human influence is significant and involves a diverse range of first-order climate forcings, including, but not limited to the human input of CO_2;**
- **The human influence is dominated by the emissions into the atmosphere of greenhouse gases, particularly carbon dioxide.**

My written testimony presents evidence that the correct scientific conclusion is that

The human influence on climate is significant and involves a diverse range of first-order climate forcings, including, but not limited to the human input of CO_2.

Modulating carbon emissions as the sole mechanism to mitigate climate change neglects the diversity of the other, important first-order human climate forcings. As a result, a narrow focus only on carbon dioxide, to predict future climate impacts, will lead to erroneous confidence in the ability to predict future climate, and, thus, costs and benefits will be miscalculated. CO_2

policies need to be complemented by other policies focused on the other first-order climate forcings.

In addition, the 2005 National Research Council Report concluded that a global average surface temperature trend offers little information on regional climate change. In other words, the concept of "global warming", by itself, does not accurately communicate the regional responses to the diverse range of human climate forcings. Regional variations in warming and cooling for example, such as from tropospheric aerosols and landscape changes, as concluded in the National Research Council report, have important regional and global impacts on weather.

The human climate forcings that have been ignored, or are insufficiently presented in the IPCC [Intergovernmental Panel on Climate Change] and CCSP [US Climate Change Science Program] reports include

- **The influence of human-caused aerosols on regional (and global) radiative heating**
- **The effect of aerosols on clouds and precipitation**
- **The influence of aerosol deposition (e.g. soot; nitrogen) on climate**
- **The effect of land cover/ land use on climate**
- **The biogeochemical effect of added atmospheric CO_2**

Thus climate policy that is designed to mitigate the human impact on regional climate by focusing only on the emissions of CO_2 is seriously incomplete unless these other first-order human climate forcings are included, or complementary policies for these other human climate forcings are developed. Moreover, it is important to recognize that climate policy and energy policy, while having overlaps, are distinctly different topics with different mitigation and adaptation options.

A way forward with respect to a more effective climate policy is to focus on the assessment of adaptation and mitigation strategies that reduce vulnerability of important societal and environmental resources to both natural and human caused climate variability and change. For example, restricting development in flood plains or in hurricane storm surge coastal locations is an effective adaptation strategy regardless of how climate changes.

In conclusion, humans are significantly altering the global climate, but in a variety of diverse ways beyond the radiative effect of carbon dioxide. The CCSP assessments have been too conservative in recognizing the importance of these human climate forcings as they alter regional and global climate. These assessments have also not communicated the inability of the models to accurately forecast future regional climate on multi-decadal time scales since these other first-order human climate forcings are excluded. The forecasts, therefore, do not provide skill in quantifying the impact of different mitigation strategies on the actual climate response that would occur as a result of policy intervention with respect to only CO_2.

Ms. BALDWIN. I would like to thank our panel of witnesses. We will now proceed to a round of questioning by members. And I will start by recognizing myself.

Ms. Goodman, when you started the CNA project, did all of the admirals and generals who participated agree that climate change was a problem that needed to be addressed or were there divergent views within the group at that point? And if there were divergent views, how did that dynamic evolve as the group heard from scientists and developed its report?

Ms. GOODMAN. In fact, when we began, I would say that many of the generals and admirals came to the project somewhat skeptical of climate change and human-induced climate change because largely they weren't familiar with the subject. And we spent some considerable period of time educating ourselves, and they learned from meeting climate scientists as well as skeptics. They met with business leaders as well as industry and government leaders and scientists. We traveled to the U.K. and met with leading climate officials there as well as leading British government officials and industry officials. And they really came to believe that this is a serious risk to national security that needs to be addressed now, and that it is prudent to begin to take the proper actions to integrate climate change into national security planning.

Ms. BALDWIN. I understand, or I think we heard in some of the opening statements that a National Intelligence Assessment for Climate Change is being released this week. What does this report say that is different from the conclusions reached by the CNA, or are the two reports, in general, in agreement?

Ms. GOODMAN. Well, I would say the National Intelligent Assessment actually validates many of the findings of our report in that climate change is a threat multiplier for instability and the National Intelligence Assessment uses a phrase of "impact of state stability" and "consequences for state stability." So they framed it in the terminology that is commonly used in the intelligence community, and they have noted, in particular, the impact on water resources over the coming decades and the potential for migrations, and so I would say, in many ways, the two reports have reached similar conclusions and confirmed that the national security impacts are quite important and warrant attention now.

Ms. BALDWIN. The Chair would next recognize Ranking Member Barton for his questions for 5 minutes.

Mr. BARTON. Thank you, Madam Chairwoman.

My first question is to Mr. McKitrick. In Lord Stern's analysis, did he include any benefits of climate change, and if so, how did he cost those, like longer growing seasons, more irrigable land, things like that?

Mr. MCKITRICK. In the Stern Review the cost of greenhouse gas emissions are put into a number of different categories. Some of them are the direct effects, which would be netted against benefits of the type you are talking about. That category, in the end, is very small. Eighty to 90 percent of the costs are indirect effects, which go under headings like social and political instability and knock-on effects, and these categories, I don't think are all that well defined in the report, and it is hard to get details of how the underlying model treats them, or what the parameters were that drove them. But those are the costs that dominate on the cost side of the ledger.

So even if there are some assumed benefits from longer growing or increased CO_2 fertilization, they are quite a bit overwhelmed by these other cost categories.

Mr. BARTON. And my next question is to Dr. Janetos and Dr. Pielke. I have begun to see pop up various climate groups talking about the goal of getting to 350 parts per million of CO_2 in the atmosphere. And my question is: where does that number come from, and what is the assumption that that is the perfect level of CO_2 to have in the atmosphere?

Mr. JANETOS. I will start if you don't mind. It is not a goal that we address in our report. In our report, what we try to do is look at the data as we understand them today, and not do an analysis of what an appropriate target goal might be. And so what we have done is look at both effects of increased atmospheric carbon dioxide in the atmosphere, longer growing seasons, as you just pointed out. We also look at the issues of the sensitivities of natural environments to phenomena like reduced precipitation, long-term drought, fire, and pests, and so on, which we are also beginning to see. We have made no attempt in our report to establish what a target might be. That is not simply a scientific question. It is also a question about values, and it is not one which we were asked to address.

Mr. PIELKE. I would answer. I think that is a very good question. I don't know how they come up with that number. And I would also point out that if you want to come up with a number in terms of how we are disturbing the human-climate system, you could do that for land-use change, or you could do it for nitrogen deposition. You could do it for aerosols. And I think the problem we see is they picked one particular disturbance of the climate system as the whole universe that they are looking at.

Mr. BARTON. Well, is it fair to say that this number does not have a scientific basis?

Mr. PIELKE. Basically it is above the preindustrial level, but other than that, it doesn't have any reality that I can see.

Mr. BARTON. I think this is something that you believe: we need to address climate change, and we need to do it sooner rather than later. Are there things we could do that would have a greater cost-benefit effect than carbon cap-and-trade, carbon taxes? Are there things like planting more forests, doing something in the oceans? I have heard all kinds of ideas put forward. I just don't have the scientific basis to evaluate them. I have even heard that you just even painted the parking lots in Los Angeles white or silver that that would have a temperature effect. And I am not saying that it would. I am asking.

Mr. PIELKE. Well, it would, but I think the first thing we have to do is separate climate policy from energy policy, and we are using climate policy to make energy policy, and I think that is a huge mistake.

When we look at climate, climate has always been changing, and we have to recognize that we have dealt with that for a long time, and we have been very successful in this country—less loss of life, for example, in the coastal regions because we have better forecasts. So I think we need to see what we can do in terms of adaptation to climate, because it has always been varying. And we always have to do things, like you say put white roofs or white parking lots in drier climates and semi-arid climates. That would be a cooling effect, and you would use less air conditioning.

But I think the bottom-line message is this is a complex issue, and we need to look at it in an integrated fashion, and there is no simple solution. It would be really great if we could just turn down carbon dioxide and we would prevent droughts and floods, but it is not that simple, and I think that has not been recognized?

Mr. BARTON. I know my time is expired, but could I have one more question?

Ms. BALDWIN. Without objection.

Mr. BARTON. Again, this is not an argumentative question. It is just an informational question. I see all of these allegations that climate change or CO_2 increases in the atmosphere are now responsible for violent hurricanes and more violent weather events, but I have not been able to find any scientific or meteorological justification for that. Could the two climatologists on the panel explain to me what the genesis is for that and what the link is?

Mr. PIELKE. Well, there are conflicting papers in the literature about increases of hurricane intensity. They are based some on data, some on models. The ones that are based on data, unfortunately, are using a data set that is not homogenous in time. So I think the bottom line is we just don't know what is the effect of all of these human disturbances on the climate system. But it seems that if you are from one side or other, you tend to pick an event and say it is attributable to CO_2, and I think that is a mistake.

Mr. BARTON. Global warming is responsible for everything.

Mr. PIELKE. Right, and I think that is mistake.

Mr. BARTON. We have a drought; we have a flood. It doesn't matter which way it goes, somebody says it is a global warming issue.

Mr. PIELKE. Well, our research has shown, I think rather convincingly that it is the regional changes that matter, not the global average temperature change anyway. So we have to be able to understand how the regions change in response to these climate forcings, and we are just not there essentially. So when I hear people say the science is done, it is far from done. If it was done, you wouldn't be funding any more science research, so it is not done.

Mr. BARTON. Doctor, let us have your view on that.

Mr. JANETOS. My view is not so different from Dr. Pielke's. I wouldn't pretend to know what the geneses of all of these assertions are. It is, I think, in some sense, a fool's errand to say that this particular storm, or this particular drought or this particular rainfall event or hurricane is the marker for climate change. That is simply making the mistake that a particular event is emblematic of what is a very clear longer term trend of change in the physical climate system.

The science on hurricanes is obviously an active scientific debate as to what has happened during the 20th Century. There are some serious model issues with projections. It requires far more computational power than we currently have to do these hurricane projections in a reasonable way.

So I think, in some sense, the jury is very much out as to what the future entails in terms of tropical storms. We are quite clear on those particular points in our assessment. What is equally clear is that the longer term trends that we have seen are already having demonstrable measurable effects on natural resources, and that is something that is not a matter of modeling results. It is a matter of data and actual observations, and that is something that I think is important to keep in mind as we consider the fate of these natural resources and the people who depend on them over the next several decades.

Mr. BARTON. Thank you, and thank you, Madam Chairwoman.

Ms. BALDWIN. Thank you. The chair now recognizes the gentleman from Utah.

Mr. MATHESON. No questions.

Ms. BALDWIN. The Chair now recognizes the gentleman from Illinois, Mr. Shimkus, for 5 minutes of questions.

Mr. SHIMKUS. No questions? I am impressed.

I appreciate the panel being here. I am curious. I just was aged out of the Army Reserves after 28 years served during the Cold War on the border, infantry officer. I think I have a little bit of background in national security and in military affairs.

The Japanese went to Southeast Asia for what? Oil. The Germans went into the caucuses for what? Oil. Our dependence upon imported crude oil is a national security concern, and it is such of a concern. I have a couple of questions. I have got zillions, but I will try to be very patient.

Ms. Goodman, do you support Gene Taylor's call for expanding the nuclear Navy?

Ms. GOODMAN. Congressman, I support a strong Navy.

Mr. SHIMKUS. But the question is not a strong Navy. The question is Gene Taylor, my friend from Mississippi, is calling for the expansion of the nuclear navy. It addresses climate. It addresses energy security. Do you support that?

Ms. GOODMAN. I think we have to look at all of the options to maintain the viability of our Navy.

Mr. SHIMKUS. Now, you sound like a politician. Yes for expansion of nuclear Navy or no?

Ms. GOODMAN. I think the Navy, itself, is considering those options now.

Mr. SHIMKUS. And is that good or bad?

Ms. GOODMAN. I think if we can maintain the record——

Mr. SHIMKUS. Do you like nuclear power?

Ms. GOODMAN. Nuclear power has been excellent for our Navy. There is absolutely no doubt about it. They have an excellent and unsurpassed safety record in managing nuclear power.

Mr. SHIMKUS. Nuclear power, does it emit any carbon?

Ms. GOODMAN. Nuclear power is a good, non-carbon——

Mr. SHIMKUS. You sound like a politician. We are the politicians up here. Does nuclear power emit carbon?

Ms. GOODMAN. No, it does not.

Mr. SHIMKUS. The answer is no. Should we expand a nuclear Navy? I believe yes. I believe that one of the greatest challenges to the world today will be fighting over energy resources. We saw it in WWII. We can see it in the future. If you are a climate change believer, the problem that many of us have is you all won't go to nuclear power. The environmental left says no nuclear power, and that is fool hearty.

And if we are talking about national security and our military ships traveling around the world and doing warfare, but also doing great humanitarian issues, I support Gene Taylor.

For every dollar increase in a barrel of oil, it costs our Air Force, the number one jet-fuel user in the world $60 million. What we have been trying to say is good American coal, good American jobs. It is actually better for capturing and sequestering carbon than a pulverized coal power plant, American jobs to operate this refinery. American jobs to produce in this refinery. Put it in a pipeline, away from the shores, the gulf coast or anything that could be affected by a Katrina, and you pump it to our jet airplanes. If you want to talk about helping the national security environment of this world, it is decreasing our reliance on imported crude oil from unstable places around the world, like Iran, like Venezuela. We have increased our reliance on imported crude oil. The only way we get out of this mess is by developing our own energy resources, which we have in the Outer Continental Shelf, we have in Alaska, we have on the east coast, we have on the west coast. We have in coal in Illinois.

So I would hope that my admiral and general friends would talk about how we operate our military war machines in this era of increasing costs and this fight over energy resources, and especially if there is an inability or unwillingness to move to nuclear power. And that is the same argument that our country has to have. We have to move to nuclear.

And Mr. Lyons, my time is running real quickly. I would submit that the higher cost of fuel today is currently doing as much if not more damage to the developing world in the food debate and in the food riots than this supposed futuristic concern. I would say, and I think the economists that are here are saying cost-benefit analysis and how do you get the biggest bang for the buck now, and what is the best way to transform?

And my last question, because I know I am running out of time. Dr. McKitrick, just this question, because I think you posed it in your opening statement, you addressed the difference between a cap-and-trade regime and a carbon tax, and I would like my colleagues to hear this, because I said in my opening statement, if you want transparency, a carbon tax is clearer. But you pose an economic principal that a cap-and-trade regime is also more costly. Can you just briefly elaborate that?

Mr. MCKITRICK. Yes, thank you for the question.

A cap-and-trade regime controls the quantity of emissions and allows the market for permits to determine the price. The government doesn't capture the rents that are created by this regime. What happens is that by controlling the quantity of emissions, the producers of energy who are allocated the permits are able to increase the price that they charge to consumers. That gap, then, doesn't go to the government who could, in principal, at least, reduce other taxes or provide some other means of recycling the revenue to households. Instead it just accrues to the owners of the permits.

There has been a lot of work in economics using what are called computable general equilibrium models to compare the effects of carbon taxes and cap-and-trade systems. And there is a kind of hidden mechanism with cap-and-trade in the way that it affects earnings to labor, real earnings, and real income, and those indirect effects, which are called the tax-interaction costs, turn out to be a large category of costs for households, but they are entirely hidden.

In terms of transparency, if you are not willing to put a $50 a ton carbon tax in front of the public and say you want to charge them that, it is not fair to do it in the form of a cap-and-trade system where the permit price turns out to be $50, because that is still the same hit for the public, but there is no offsetting benefit in terms of income tax reductions financed by a carbon tax, and that is where the extra costs come in for the cap-and-trade system.

And one of the reasons cap-and-trade doesn't work very well for carbon dioxide emissions is there are so few abatement options that firms can't really cut their emissions. They just have to keep cranking up the prices until the demand falls enough that they meet their permit allocations. And because they have very few emission reduction options it is not like sulfur dioxide. It is not like particulates. It just translates into large price shocks for consumers. The carbon tax system allows you to put a cap on the price shock, and that is very important if you are interested in protecting households from the economic consequences.

Ms. BALDWIN. As this hearing winds to a close, the chair would allow either Mr. Lyons or Ms. Goodman to respond to that same last question.

Mr. LYONS. I appreciate that, Madam Chairman. Thank you very much. And I appreciate the question, Mr. Shimkus, and I wouldn't disagree with you on the energy-cost quotient. There is front-end cost associated with inputs, and there is certainly a high cost associated with transportation.

I guess where I would disagree with you on the notion that there is some futuristic element to climate change. I think all of the evidence would indicate that there are real impacts being felt now, that these are being documented, not only by scientists, but if I could quote from the intelligence estimate that was presented to the Congress yesterday, "scientific studies indicate that climate change is likely to cause agricultural losses, possibly severe in the Sahel, west Africa and southern Africa. Agricultural yields from some rainfall-dependent crops could be reduced by up to 50 percent by 2020." So those represent real, environmental induced costs.

I know we are running out of time. And I guess the third thing I would point out is I would be glad to submit for the record if you would like an explanation of the 350 parts per million, the scientific basis for that. I am not an economist, thank God, but I know a little bit about science.

Mr. SHIMKUS. And if I may, I would say in the statement you just said, of course, that 50 percent could be. I have no time, but I am happy to debate this as long as the chair would allow us to debate this.

Ms. BALDWIN. Not much longer, but go ahead.

Mr. LYONS. The IPCC report is based on a 90- to 95-percent confidence in the observations included in the report, and it includes scientists worldwide, including scientists from the United States. So as was discussed earlier, this is a matter of understanding risks and probabilities, but here there is a high probability in what they have observed. That is all I would offer for the record.

Ms. BALDWIN. Ms. Goodman?

Ms. GOODMAN. Thank you very much, Madam Chairman. Mr. Shimkus, I just wanted to clarify that I support continued and possibly increased reliance for our U.S. Navy. It has indeed been an essential source of power for our naval vessels. I would observer, however, that coal-to-liquids, unlike nuclear power, is not presently a carbon-free solution unless we make substantial investments in carbon-sequestration technology, which we have not yet materialized, but I hope it will in the future.

Mr. SHIMKUS. If I may, Madam Chairman, if we went—with today's prices, that would free up $192 billions of additional revenue to do all of these things and all of this scientific movement into this "new Manhattan project" because it is going to be costly, and we have got to find the money to do that.

Ms. BALDWIN. With that, I want to thank the witnesses for your testimony today. And the Chair announces that our hearing on Climate Change: the Cost of Inaction is adjourned.

[Whereupon, at 1:55 p.m., the subcommittee was adjourned.]

[Material submitted for inclusion in the record follows:]

PREPARED STATEMENT OF HON. TOM ALLEN

Chairman Boucher, thank you for holding this hearing on this important topic. Thank you also to all of the witnesses here before us today. I look forward to your testimony.

One of the primary criticisms of legislation to curb greenhouse gas emissions is the potential cost of the legislation on consumers. Consumers are worried they will see increased costs at the pump, on their electric bill and throughout our economy. However, we are seeing the cost of climate change impacts now. Climate change threatens our farms, our oceans and our national security. The cost of doing nothing could far outweigh the cost of taking action.

Climate change leads to a multitude of effects on all aspects of ecosystems from farmland to water supplies. Right now food prices are high and crop supplies are low, and climate change could further exacerbate this problem. It is very likely that crop yields will decrease as the temperature rises. In addition, it is likely that increasing carbon emissions have already increased the frequency of forest fires and pest invasions in the Western United States. Climate change may also lead to a decrease in precipitation in some areas as well as increasing evaporation in other areas. Decreasing water supplies impact ground water, water reservoirs and ultimately water quality and human health.

Even our substantial oceans are not immune from climate change impacts. Approximately one third of the carbon dioxide released by the burning of fossil fuels ends up in the oceans, causing ocean acidification. Ocean acidification can impede shell formation in marine shellfish and is harmful to many organisms essential to ocean food webs. These species include corals, shellfish and plankton; all of these species are essential to the food chain for many larger fish and marine mammals. Research by scientists at St. Joseph's College in Standish, Maine has revealed that ocean acidification, due to climate change, may substantially increase the mortality of young clams, threatening a $16 million industry and the livelihoods of 1,800 commercial clam diggers in Maine alone.

This administration has long touted national security and stability in the Middle East as important goals, yet they reject legislation on one of the biggest threats; climate change. Climate change adds stress to already tense and hostile areas and could lead to sustained natural disasters and humanitarian crises far worse than those we see today. Impacts from climate change will threaten populations in Asia, Africa and the Middle East that are already stressed from lack of food and adequate water supplies. As food production further declines and water becomes scarcer large numbers of people will move in search of these crucial resources. Large scale migrations could cause political unrest and increases the likelihood of failed states and weakened governments. As we have seen before, increasing conflict breeds extremism and radical ideologies. Climate change has the potential to dramatically alter the political landscape.

Climate change is not just a problem facing polar bears. Our drinking water, our farmlands, and our national security are all threatened by the lack of action on climate change legislation. The cost of doing nothing is a price we can no longer afford.

Prepared Statement of Hon. John B. Shadegg

Thank you Mr. Chairman for holding this hearing.

I welcome this discussion on the costs of climate change and would like to offer my perspective on where I see the highest costs. Given the record-high energy prices of today, I think we would be putting the American people in grave peril if we were to pursue any of the various climate change proposals before this Congress. For example, Senator Boxer's amendment to S. 2191, of the Lieberman-Warner Climate Security Act is estimated to cost a staggering $6.7 trillion. It is naive to believe that this cost will not be passed on directly to the American consumer.

An analysis of the effects of S. 2191 on my state of Arizona shows a potential loss of 34,699 jobs by 2020 and 84,543 jobs by 2030. Arizonians would see a decrease in disposable household income of $6,617 by 2030. Gasoline prices in Arizona would increase as much as 140% by 2030 and electricity prices would increase up to 133%. Overall, this legislation is estimated to reduce Arizona's gross state product by $2.6 to $3.6 billion by the year 2020 and $9.6 to $11.3 billion only a decade later.

It is the upmost importance that Congress balances the need for any policy to properly balance cost with resulting benefits. However, this legislation results has no such benefit. According to the Environmental Protection Agency, S. 2191 would only decrease global temperatures by only one tenth of one degree Celsius; I am not sure that my constituents, in the third congressional district of Arizona, will believe that it is worth $6.7 trillion for a global temperature change equal to less than one degree Celsius.

Many on this Subcommittee share these concerns. I want to thank our witness panel for their testimony today and I look forward exploring the issue further. Thank you.

Anthony Janetos, Response to Question from Hon. John D. Dingell

Is the tropical troposphere more or less sensitive to climate change than the troposphere at the poles?

The tropical troposphere is not inherently different in its sensitivity to climate change than the troposphere in other regions. The major greenhouse gases produced by human actions (e.g. carbon dioxide, methane, nitrous oxide) are globally distributed and well-mixed, and the particular locations of their sources and sinks is not important from an atmospheric perspective over the long term.

The tropics are nevertheless extraordinarily important in climate change. The tropical troposphere is an area of deep convective processes that promote atmospheric mixing; it also has higher water content than the polar troposphere, in large part because it is so much warmer, and it is thus an important region to understand. The tropics are also a major source of fluxes of carbon dioxide to the global atmosphere from land-use change, largely the result of the conversion of forests to agricultural lands.

There is a general expectation from both theory and models that changes in annual surface temperature from climate change will actually be greater as one moves towards the poles and away from the tropics. There is observational evidence that this phenomenon is indeed occurring, and this forms one of the many signatures that have led the IPCC to conclude that human activities are a major contributor to the observed warming seen globally over the past century.

Jim Lyons, Response to Question from Hon. John D. Dingell

1. At the hearing, a question was raised about the scientific basis for suggesting that we should be aiming for global atmospheric CO_2 concentrations of 350 ppm. One witness testified that there is no scientific basis. Do you agree? If not, please explain why not.

The Intergovernmental Panel on Climate Change estimates in their Fourth Assessment Report that 350 09400 parts per million (ppm) of CO_2 would increase global average temperatures from 2.0 092.4°C above pre-industrial levels (see table below). Global average temperature rise above 2°C above pre-industrial levels would likely generate the most dangerous impacts of climate change, such as extremely harmful levels of water scarcity, severe weather events, decreased agricultural productivity, exacerbated disease, and ecosystem degradation.

Given these findings, stabilizing CO_2 at 350 ppm would keep temperature rise at the low end of IPCC's estimate, making it more probable that temperature increases remain at or below a 2°C global temperature change.

Table from IPCC's Fourth Assessment Report, Summary for Policymakers (p. 20):

Table SPM.6. Characteristics of post-TAR stabilisation scenarios and resulting long-term equilibrium global average temperature and the sea level rise component from thermal expansion only.[a] (Table 5.1)

Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d,e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Notes:

a) The emission reductions to meet a particular stabilisation level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).

b) Atmospheric CO_2 concentrations were 379ppm in 2005. The best estimate of total CO_2-eq concentration in 2005 for all long-lived GHGs is about 455ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375ppm CO_2-eq.

c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios (see Figure SPM.3).

d) The best estimate of climate sensitivity is 3°C.

e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilisation of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150 (see also Footnote 21).

f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low-resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere-Ocean General Circulation Model and EMICs to Earth System Models of Intermediate Complexity.)

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November 4, 2008

US House of Representatives
Committee on Energy and Commerce
Washington DC 20515-6115

Dear Chairman Dingell

Thank you for the opportunity to answer some additional questions.

1. *In your testimony, you state that "a considerable amount of work has gone into estimating potential economic consequences of global warming induced by greenhouse gas emissions." You cite a survey by R.S.J. Tol of 211 estimates of the marginal cost of greenhouse gas emissions. Is any of your work included in that survey of 211 estimates?*

   Table A1 from

   > Tol, R.S.J. (2007) "The Social Cost of Carbon: Trends, Outliers and Catastrophes" Discussion Paper 2007-44, Economics e-journal, September 19 2007.

   provides the listing of the 211 studies in Tol's meta-analysis. I am not an author or coauthor on any of them.

2. *I understand that you have published critiques of other economists' analysis of the marginal cost of greenhouse gas emissions. Have you published your own analysis of the marginal costs of greenhouse gas emissions? If so, please provide a citation to your paper.*

   My coauthored critique of the Stern review's estimates of the marginal costs of greenhouse gas emissions is

   > Byatt, I., R. M. Carter, I. Castles, et al. 2006. The Stern Review: A Dual Critique. *World Economics* 7, no. 4: 165-232.

I have not published an estimate of the marginal damages of greenhouse gas emissions. I have published analyses on the related matter of how pricing instruments for internalizing the marginal costs of greenhouse gas emissions should be tied to estimated marginal damages. Citations include:

McKitrick, Ross R. (2001) "Mitigation versus Compensation in Global Warming Policy." *Economics Bulletin*, Vol 17 no. 2 pp. 1-6, 2001.

McKitrick, Ross R. (2008) "A Simple State-Contingent Pricing Rule for Complex Intertemporal Externalities." Social Sciences Research Network Discussion Paper No. 1154157, July 1, 2008.

3. *Is the tropical troposphere more or less sensitive to climate change than the troposphere at the poles?*

I believe you mean "more or less sensitive to *greenhouse gases*". I will answer the question first with reference to the predictions of models and then with reference to the observed data.

MODELS

Climate models in which greenhouse gases are assumed to be capable of causing significant global warming show greater sensitivity to greenhouse gases in the troposphere over the tropics than over the poles.

The 2007 Intergovernmental Panel on Climate Change (IPCC) Report, Working Group I, Figure 9.1 (p. 675) presents a "backcast" analysis of the atmospheric response to observed changes in major forcings (greenhouse gases, solar radiation, volcanoes, aerosols and ozone depletion) over the interval 1890 to 1999 using the Parallel Climate Model (PCM), a large general circulation model sponsored by the US Department of Energy. The IPCC Figure is reproduced on the next page. I have added titles to the panels for ease of reading. All models are similar in behaviour, as the IPCC Report states (p. 674) that "The major features shown in Figure 9.1 are robust to using different climate models."

The format of each panel is as follows. Latitude goes from left to right, with the North Pole at the left, the equator in the middle and the South Pole at the right. Altitude is on the vertical axis, beginning at the surface and rising through the troposphere and into the stratosphere. The colour represents the predicted temperature change in response to the forcing. Dark blue and purple represent strong cooling. As the shading moves through light blue, light yellow and into orange and red the implied temperature change moves upwards towards strong warming.

I have added a horizontal line in the Greenhouse Gases panel indicating the approximate height of the mid-troposphere: just over 8 km at the poles, rising to about 12 km in the tropics.

As is clear from the coloring gradient, the model troposphere over the tropics shows greater sensitivity to greenhouse gas accumulation than does the troposphere over the polar region. The color tones indicate that, in response to 20[th] century greenhouse gas accumulation, the model says there ought to have been a warming rate of over 1 C per century in the troposphere over the tropics, and about 0.4 C per century in the troposphere over the poles. This pattern is sufficiently large in comparison to all other forcings that it dominates the Total forcing pattern in the bottom right panel.

Chapter 9 Understanding and Attributing Climate Change

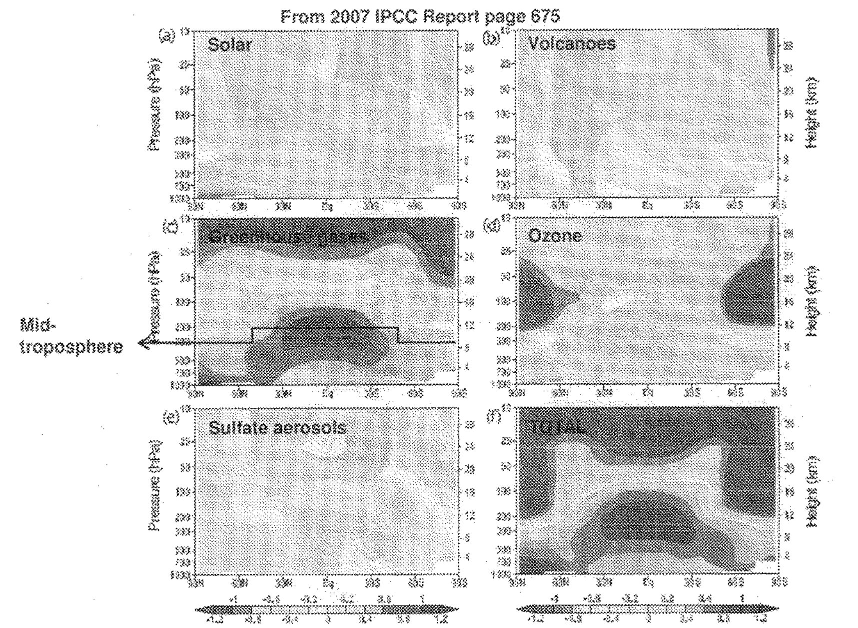
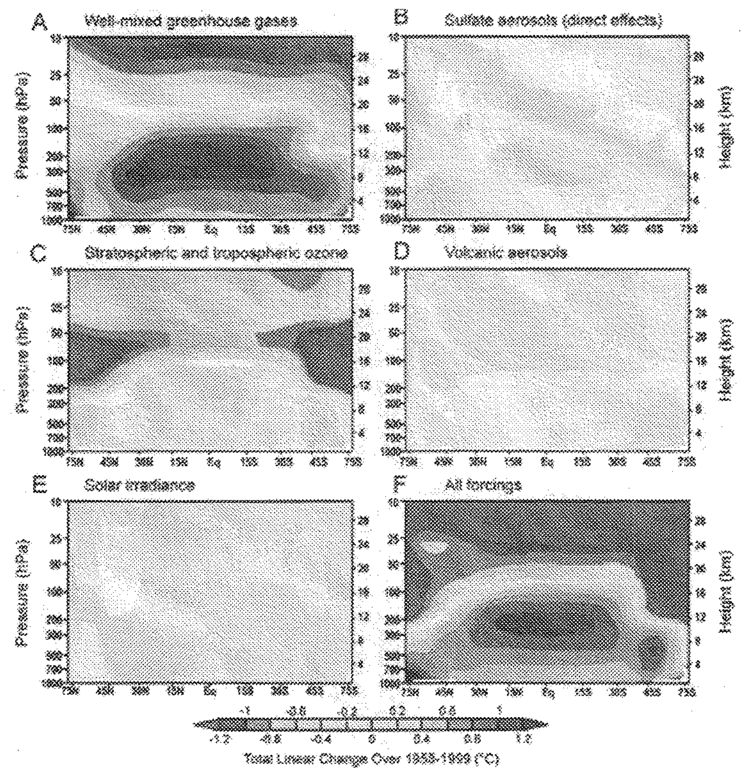


Figure 9.1. *Zonal mean atmospheric temperature change from 1890 to 1999 (°C per century) as simulated by the PCM model from (a) solar forcing, (b) volcanoes, (c) well-mixed greenhouse gases, (d) tropospheric and stratospheric ozone changes, (e) direct sulphate aerosol forcing and (f) the sum of all forcings. Plot is from 1,000 hPa to 10 hPa (shown on left scale) and from 0 km to 30 km (shown on right). See Appendix 9.C for additional information. Based on Santer et al. (2003a).*

The US Climate Change Science Program (CCSP) presented very similar results for a more recent interval. On the next page I have reproduced Figure 1.3 (p. 25) from the 2006 CCSP Report *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences.* It is similar in structure to the above IPCC diagram, and comes from the same model (PCM), but covers the interval 1958-1999. The color coding indicates once again that the troposphere is expected to be more sensitive to greenhouse gases over the tropics than over the polar regions (though note that regions beyond 75N and 75S are not displayed). In this case the warming rate in the mid-troposphere over the tropics is projected to be between 1.0 and 1.2 C over a 40 year span, or about 0.25-0.30 °C/decade, versus about 0.05-0.10 °C per decade over the poles, in the decades ending at 1999.

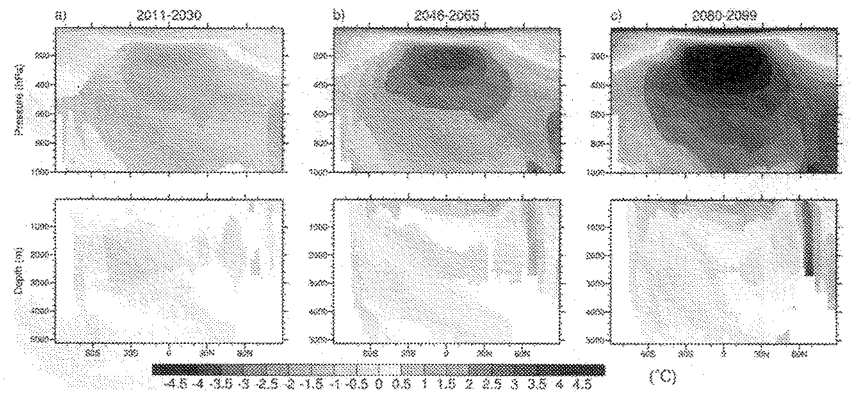
PCM Simulations of Zonal-Mean Atmospheric Temperature Change
Total linear change computed over January 1958 to December 1999



Turning now to projections of the climatic response to future increases in greenhouse gases, on the next page I have reproduced one of the 12 climate model projections used for Figure 10.7 of the IPCC Report (p. 765). The models show the response to the A1B emissions scenario, which is in the middle of the group of IPCC climate simulations (see IPCC Figure 10.4). All 12 model runs are available on-line at http://ipcc-wg1.ucar.edu/wg1/Report/suppl/Ch10/Ch10_indiv-maps.html. The printed version of Figure 10.7 uses stippling to show the uniformity of results across models, but this makes it harder to see the color gradients, so I have selected the output from a single model, the Goddard Institute of Space Studies (GISS) model EH, for increased clarity.

The panels in the top row are each in the same format as those in the PCM diagrams above, except that, going from left to right, latitude runs from South to North, and the vertical axes do not extend as far up into the stratosphere. The bottom three panels show projected oceanic changes.

GISS-EH



Source: http://ipcc-wg1.ucar.edu/wg1/Report/suppl/Ch10/indiv_maps/html/GISS-EH_10.7.html

The color coding indicates, over the indicated interval, the predicted change in the mean temperature compared to the observed mean temperature over the 1980 to 1999 interval. As before, the mid-troposphere over the tropics (300-200hPa) is projected to be more sensitive to increased greenhouse gas levels than the troposphere over the polar regions, in all time intervals. The accompanying text (pp. 764-765) states:

> Upper-tropospheric warming reaches a maximum in the tropics and is seen even in the early-century time period. The pattern is very similar over the three periods, consistent with the rapid adjustment of the atmosphere to the forcing. These changes are simulated with good consistency among the models.

As of the 2011-2030 interval the troposphere over the tropics is projected to be about 1.5 °C warmer than the average temperature over the 1980 to 1999 interval. Comparing interval midpoints (1990, 2020) this implies a current average warming of 0.5 °C per decade, noting once again the statement in the IPCC text that this change should be observed even in the early-century time period.

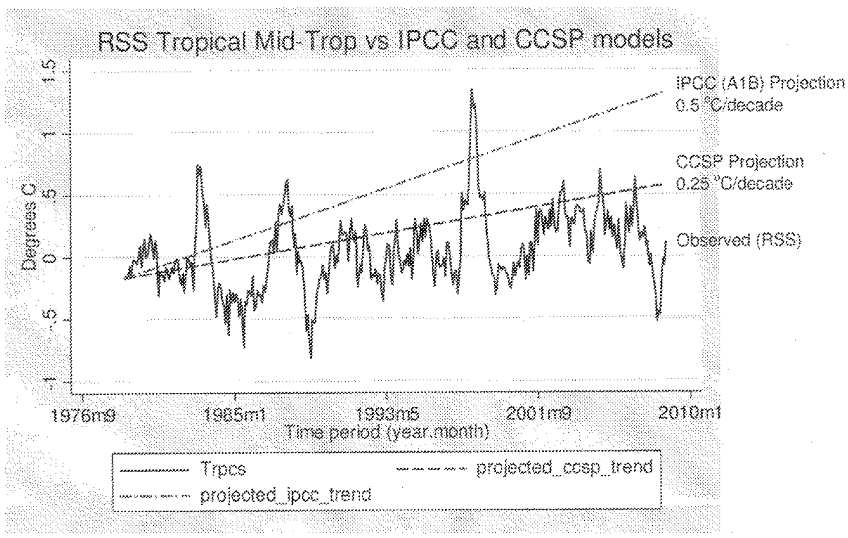
To summarize thus far, all the models which have been used for the IPCC and CCSP reports embed parameterizations that yield the following predictions:

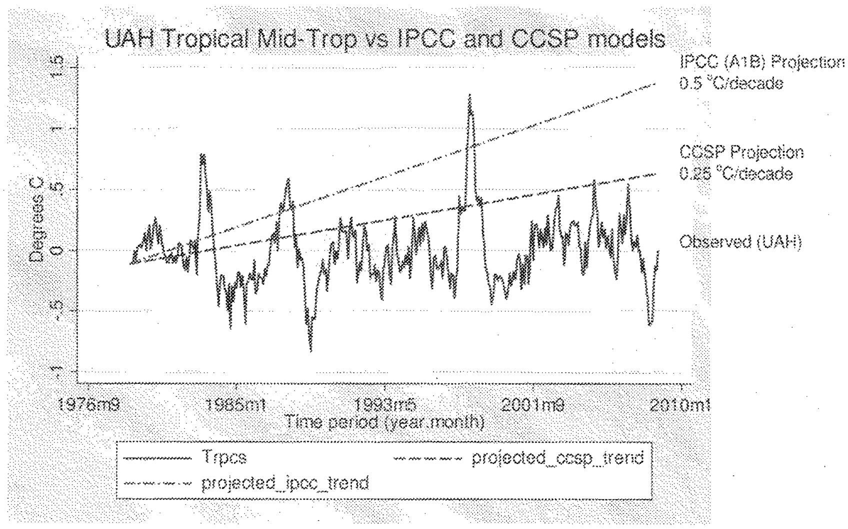
- The troposphere over the tropics should exhibit greater warming (more than double the rate) than the troposphere over the polar regions.
- The effects induced by greenhouse gases are so large relative to other forcings (positive and negative) that the total pattern is predominantly a reflection of the contribution of greenhouse gases.
- The tropical troposphere should have been heating up at a rate of at least 0.25 °C/decade over the past few decades in response to historical greenhouse gas emissions. A middle-range warming projection scenario in the IPCC report predicts warming of about 0.5 °C/decade should now be observable in the tropical mid-troposphere.

DATA

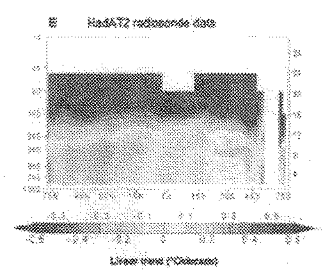
Weather satellite records for the mid-troposphere are available from Remote Sensing Systems (RSS) in California and the Earth Systems Science Center at the University of Alabama-Huntsville (UAH). I obtained the data from each lab for the mid-troposphere layer covering January 1979 to September 2008. Over this interval the annual average atmospheric concentration of CO_2 measured at Mauna Loa Hawaii rose from 337 ppm to 384 ppm (http://cdiac.ornl.gov/ftp/trends/co2/maunaloa.co2), a 14% increase. I have graphed the RSS and UAH tropical mid-troposphere series and compared them to the CCSP- and IPCC-predicted trends (0.25 °C/decade and 0.5 °C/decade respectively).

In contrast to climate model predictions the data indicate neither significant warming in the tropics nor greater warming than at the poles.





The CCSP report (Figure 5.7, p. 116) presented an atmospheric weather balloon series for the interval 1979-1999, (Hadley AT2) in a format similar to the backcast panels. Note that data over Antarctica is not shown.



From the color coding one can readily tell that, like the satellites, this balloon record exhibits no overall warming pattern in the tropical troposphere: instead there is slight cooling at lower altitudes, and minimal warming at the upper altitudes. The tropospheric warming is at a lower rate than in the troposphere as a whole and lower in comparison to the North Pole region. The CCSP text (fn 66, p. 115) points out that this data span includes the 'end-point effect' of the powerful 1998-1999 El Nino so the absence of tropical tropospheric warming is an even more conspicuous discrepancy with the models.

I computed linear trends (in °C/decade) for the most up-to-date RSS and UAH data, which are as follows. An asterix (*) denotes the trend is statistically significant, i.e. distinguishable from random fluctuations.

Atmospheric Region	Remote Sensing Systems	University of Alabama
	Temperature trend in C/decade, 1979:1 to 2008:9 (Std Error of trend in parentheses)	
Globe	0.09* (0.042)	0.04 (0.040)
North Pole	0.25* (0.058)	0.23* (0.058)
Northern Hemisphere	0.15* (0.045)	0.09* (0.040)
Tropics	0.11 (0.074)	0.03 (0.071)
Southern Hemisphere	0.03 (0.036)	-0.01 (0.034)
South Pole	-0.11 (0.070)	-0.12 (0.073)

Temperature trends in mid-troposphere, January 1979 to September 2008. Sources: http://www.remss.com/pub/msu/monthly_time_series/RSS_Monthly_MSU_AMSU_Channel_TMT_Anomalies_Land_and_Ocean_v03_2.txt http://vortex.nsstc.uah.edu/data/msu/t2/uahncdc.mt Trend regression computed using STATA arima(1,0,1) specification: code posted at http://ross.mckitrick.googlepages.com/S.Dingell.zip.

The satellite data reveal warming in the mid-troposphere over the northern high latitudes but little elsewhere: in particular none over the Southern Hemisphere and a cooling trend at the South Pole. Both satellite series confirm the absence of a significant warming trend in the tropical mid-troposphere.

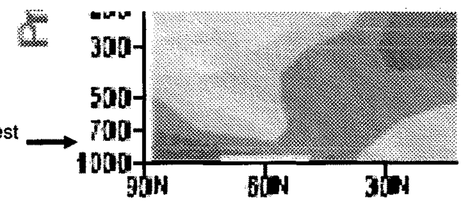
In both the RSS and UAH data sets there is a slight upward global trend, which in neither case exceeds 0.1 °C per decade over the past 30 years, despite the addition of 47 ppm CO_2 to the atmosphere. This is well below the range of 0.25-0.5 °C/decade predicted by climate models. In both the RSS and UAH series the tropical trend about equals the global trend, whereas models predict it should exceed the global trend and be at least double that over each pole. In neither data set does the tropical region exhibit a larger trend than the North Pole; and in both data sets the South Pole has cooled, opposite to the backcast results in the IPCC and CCSP reports.

The satellite series differ in part because of their treatment of inter-satellite calibration in the early segment, with the RSS series initially tracking lower than the UAH series, yielding higher trend values over the entire sample. But over the past decade (January 1999 to September 2008) the UAH series has exhibited larger warming trends than the RSS data, and no region exhibits statistically significant warming in either data set. The RSS series since 1999 shows cooling over the Southern

Hemisphere, and a global trend of only 0.006 °C/decade, despite a 4% rise in atmospheric CO_2 over this interval.

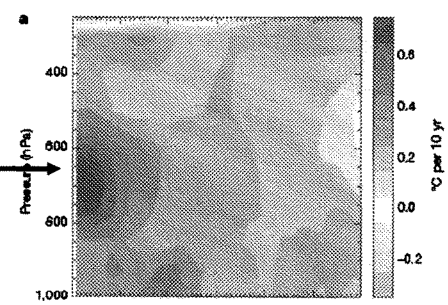
The strong warming in the mid-troposphere over the North Pole deserves some comment. Models predict amplified warming over the North Pole due to an "albedo" effect: as snow and ice melt the reflectivity of the surface declines and more heat is absorbed, increasing the local infrared radiation and the subsequent greenhouse warming. Because the mechanism operates at the surface there is a distinct vertical pattern to it: the GHG-induced warming is supposed to be strongest at the surface, then weaken with altitude.

From IPCC Figure 9.1:
Models predict GHG warming is strongest at the surface then weakens higher up



But a recent paper in *Nature* (Graversen et al. "Vertical structure of recent Arctic warming, *Nature* vol 541, 3 Jan 2008, 53—57) reported that, except in the Spring, the warming is stronger aloft than at the surface, opposite to the expected pattern (in the Spring the warming is uniform up to 700 hPa).

Observed summer half-year warming (1979-2001, April-Oct) concentrated in lower troposphere, not at surface



(Fig. 4a, Graversen et al. 2008)

They also noted that amplified North Pole warming is observed in winter months when there is so little sunshine that the albedo effect cannot be influential. This vertical and seasonal warming structure is inconsistent with the albedo mechanism in climate models. Graversen et al. showed that the trends can largely be explained by variations in atmospheric energy transport, in particular the atmospheric northward energy transport (ANET) index, a measure of wind-borne heat crossing the 60^{th} parallel latitude. The ANET index has increased in recent decades. Graversen et al. do not determine why this is so, but point to its connection with cloud cover, large-scale oscillations and planetary waves. Carbon dioxide may affect these processes but such a connection would be indirect and obscure, and is not represented in climate models. The authors conclude that much of the present

Arctic warming appears linked to processes other than the albedo-driven greenhouse amplification mechanism in climate models.

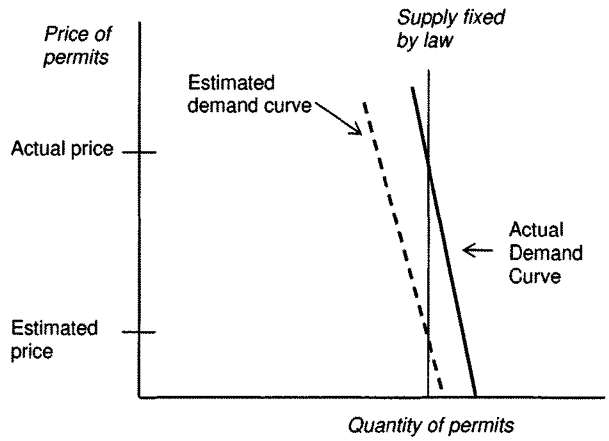
Overall, in answer to your question, climate models project that, if greenhouse gases dominate the climate, the troposphere over the tropics and over both poles should be warming; the tropical troposphere should be warming two to three times faster than the polar tropospheric regions, namely at a rate of about 0.25 to 0.5 °C/decade, and the polar warming should be strongest at the surface. The data, however, do not support any of these hypotheses. They show, at most, a trend of about 0.1 °C/decade in the tropical mid-troposphere, it is statistically insignificant and recently the annual mean temperature has fallen below the level observed in the early 1980s, despite an overall 14% increase in the atmospheric CO_2 content since that time. The trend observed in the tropics over the past 30 years is less than half that observed over the North Pole, and the troposphere over the South Pole is cooling, not warming. The enhanced trend over the North Pole has been attributed to variations in atmospheric heat transport, and the vertical structure is inconsistent with the pattern predicted in models as an amplified response to greenhouse gases.

One of my biggest concerns about cap-and-trade systems is that they ask the people of the US to commit to permanently higher energy costs based global warming forecasts from models that appear systematically to overestimate climate sensitivity to greenhouse gases and hence the environmental costs of emissions. In a subsequent question you ask about pricing in risk, so I will return to this issue below.

4. *Your testimony states that carbon taxes can more easily alleviate the regressivity of higher energy prices (from either a carbon tax or a cap-and-trade system) because offsetting tax reductions can be directed towards low-income houses. Do you agree that, if the Government auctioned all allowances in a cap-and-trade system (instead of giving them away for free) then the Government could address regressivity by directing offsetting tax reductions to low-income households? If you disagree please explain why.*

I would agree with this statement if the auction were a one-time event and the demand curve for permits were not too steep. But what is being proposed is a repeated (annual) event in which a fixed supply of permits is auctioned into a market with a very steep demand curve, the position of which is closely tied to output and energy consumption and which therefore is prone to shift over time. This makes it difficult to forecast the permit price and the resulting revenue from the auction. Therefore the size of the necessary tax reductions cannot be estimated from year to year except with large error.

The diagram below uses the geometry of demand-supply analysis to show a hypothetical example. A steep demand curve means that relatively large price increases are needed to reduce the quantity demanded. A small error in forecasting the demand for permits (the gap between the dotted and solid demand curves) translates into a large error in the estimate of the permit price. This would cause a correspondingly large error in the estimated total auction revenues and the corresponding estimate of the required compensation for low-income compensation households. Hence it would be difficult to write a budget that commits to compensatory tax cuts of anywhere near the correct magnitude from one year to the next.



If, however, the policy had taken the form of an emissions tax at the estimated price, the steepness of the demand curve ensures that, even with the gap between the estimated and actual demand curves, the resulting quantity of emissions would be close to the estimated quantity, and the resulting tax revenues and required compensation for low-income compensation households would be close to the initial estimate. For this reason, budgeting for compensatory tax cuts would be much more feasible under an emissions tax regime.

The demand curve for sulfur permits is not as steep as that for carbon permits, yet the price of US Acid Rain Allowances has nonetheless been extremely volatile: from July 2005 to January 2006 prices rose from just over $500 to over $1500 per tonne, then fell to below $500 by July 2006, spiking back to over $700 per tonne in July 2007 before retreating to about $550 per tonne in the fall of 2007. We can expect even greater volatility in carbon permit markets unless price guarantees are in place.[1]

The reason the demand curve for permits is likely very steep is that CO_2 control options are very limited compared to sulfur dioxide. All the reductions in SO_2 emissions during the first phase of compliance with the 1990 Clean Air Act Amendments came about through installing scrubbers and switching to low-sulfur sources of the same fuel. But there are no scrubbers for CO_2 and there is no "low-carbon" version of coal or oil. The only large-scale CO_2 abatement options, for the foreseeable future, are to reduce energy consumption or switch to different fuel types, which are very costly at the margin. This translates into a steep demand curve, i.e. a likelihood of rapidly increasing bid prices for permits.

[1] See http://www.chicagoclimatex.com/news/publications/pdf/CCXQ_Spr06.pdf and http://www.chicagoclimatex.com/docs/publications/CCFE_sulfurmkt_V4_i11_nov2007.pdf

5. *Your testimony states that, in the economics literature, marginal cost estimates of greenhouse gases are in the range of $20 a tonne of CO_2-equivalent. Do these estimates put a dollar value on loss of ecosystems or species extinction? If so, please explain.*

   Yes, some studies do, though the methodologies differ. For example, Hope (2006) uses the PAGE2002 Integrated Assessment Model (the same one used for the Stern Review) and embeds valuation for risks to unique and threatened ecosystems as well as the possibility of abrupt or extreme events. This study yielded a marginal damage estimate of about US$5 per tonne of CO_2 (or US$19 per tonne of carbon). Also, as discussed in the Stern Review (Chapter 6 pp. 147—148) the models of Tol and Nordhaus include ecosystem changes.

   The Stern Review obtained much higher numbers using the Page2002 model by programming in very high climate sensitivity parameters, and adding in new damage categories of a rather speculative nature, most of which do not begin to accumulate in the model until some time in the 22nd century. Then, by using a very low discount rate, high damages occurring 100 to 200 years from now are valued as being nearly equivalent to damages today. The Stern Review justified using high sensitivity parameters by referring to what it considers to be an increasing probability of global warming occurring at a rate of 5—6 °C/century (e.g. p. 151). A surface warming rate of 5—6 °C/century would imply warming in the tropical troposphere of approximately 1.0—1.2 °C/decade, some 10 times the actual, observed rate. The Stern Review does not explain how it concluded this outcome has become more likely even though the available data shows the opposite.

   Reference: Hope, C (2006). "The Marginal Impact of CO_2 from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern." *The Integrated Assessment Journal* 6(1) 19—56.

6. *Multiple leading scientists have warned us of potential "threshold" effects of climate change, where various temperature increases can provoke sudden and potentially self-reinforcing swings in environmental stability. One such example would be large-scale melting of the permafrost, which would release even more potent methane emissions. Another would be the collapse of Greenland and Antarctica ice sheets over land, which could dramatically raise sea level. How, if at all, does a marginal estimate of the value of any particular single tonne of CO_2 take the risk of surpassing these tipping points into account?*

   Integrated Assessment Models attempt to price in the possibility of a dramatic climate change in much the same way as investment models try to price in the possibility of major default or other calamity: by adding a "risk premium" to the price based on the wideness of the range of possible outcomes and the losses or gains associated with extreme events. If it were known that damages due to global warming had a mean value of, say, $10, the appropriate emissions price would be different if the possible range were -$20 to +$250 as opposed to $5 to $15. If we had to commit now to an emissions price, we would need to add a premium to the price in the former case to account for the risk that the damages might be far higher than forecast.

   If a study appears in the literature that points to the possibility of abrupt or extreme climate change causing trillions of dollars in future damages, it does not mean the risk premium should automatically increase. It depends on how likely the scenario is and how credible the numbers are. That is why

Tol's surveys include efforts to assess the credibility of the study, based on whether it was peer reviewed, what discount rate was applied, and so forth.

I don't find these points very satisfactory as an answer to your question, however. The reality is that nobody can forecast major, abrupt climate changes, but if such events are possible, the cost of trying to prevent them through elimination of fossil fuel use would be extraordinarily high. Hence you and your colleagues must weigh uncertain warnings of massive ecological dangers against the more certain matter that the putative remedies would cause massive economic dangers. I do not believe that the science (such as it is) of computing risk premiums is the right tool for sorting this out. Instead, in my testimony I drew attention to the need to use what we call state-contingent strategies, which build into the policy framework a direct feedback between the observed severity of the problem and the stringency of the policy. If done right, a feedback mechanism would help you avoid the costs of taking too much or too little action by tying the emissions price (or cap) to the actual amount of warming that is observed.

None of the proposals before Congress do this. Instead they try to strike an impossible compromise between supporters of aggressive controls on CO_2 emissions who fear that weak targets will not be tightened in the future even if the situation looks more and more dangerous, and opponents of action who fear that restrictions on CO_2 will become an unchangeable status quo even if global warming is decisively refuted over the coming decade (as I expect it will be).

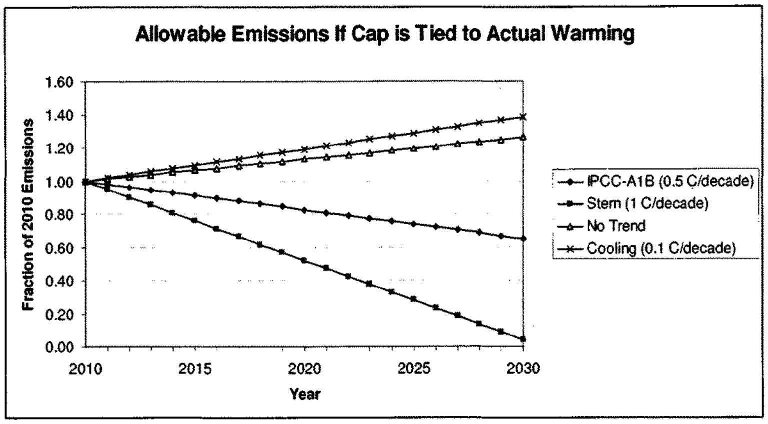
A risk premium formula cannot solve this dilemma, no matter how complex the calculations are. But a simple feedback (or state-contingent) mechanism can. For a cap and trade system it would work as follows. Since 1960, US greenhouse gas emissions intensity declined, on average by about 1.7% per year, while the US economy grew, on average, by about 3% per year. So without any regulation, if global warming were not an issue, you would expect an average increase in greenhouse gas emissions of about 1.3% per year. Now suppose we impose the following requirements on any emissions cap rule:

» If, as of 2010, the IPCC mid-range (A1B) scenario is true, the cap should decline by 35% between 2010 and 2030, in line with many of the proposals before Congress.
» If the Stern Review worst-case scenario is true (1 °C/decade in the tropical troposphere) the emissions cap should fall by 95% by 2030.
» If there is no trend in the mean temperature of the tropical troposphere between 2010 and 2030, the cap on emissions should grow by 1.3% per year.
» If the tropical troposphere starts cooling in 2010 the allowed emissions level could rise faster than 1.3% per year.
» If there is a sudden increase in global average temperatures the cap should suddenly tighten in response.

The formula that yields this outcome is

$$CAP(t+1) = CAP(t) + 0.013 - (CHANGE \times 0.61) \qquad (1)$$

where CAP(t) is the cap in year t, expressed as the fraction of 2010 emissions, CHANGE is the observed change per year in the mean temperature of the tropical troposphere from RSS or UAH (or both, averaged), and 0.61 is the number needed to yield the desired slopes. As of 2030, CAP would equal 0.65 (i.e. a 35% emissions reduction) if the A1B warming rate is observed after 2010, it would equal 0.04 (i.e. a 96% emissions reduction) if the Stern "High Sensitivity" rate is observed, it would equal 1.26 if there is no warming trend, and it would rise to 1.38 if there is a 0.1 °C/decade cooling trend. The paths look as follows.



By tying the cap to the actual warming rate it ensures you end up with the most appropriate outcome regardless of whose forecast is right. It would also force the private sector to make an unbiased assessment of the credibility of different forecasts and invest based on which ones are consistently the most accurate, since the actual abatement targets will depend on actual warming, not model forecasts.

Someone who believes in a Stern-type future would have every reason to support this formula since they would expect it to yield radically reduced greenhouse gas emissions over the next two decades. Likewise, someone who dismisses the possibility of global warming altogether should equally support this formula since they would expect the emissions cap to rise fast enough to ensure a permit price of zero. Hence the state-contingent approach avoids the political fight associated with trying to estimate a risk premium.

Tying the emissions cap to actual warming also provides a constructive way of dealing with the threat of abrupt climate changes, or "tipping points." If the future path of warming is minimal for a while, then suddenly switches to an abrupt warming trend, the above formula would instantly tighten the allowable emissions. More importantly, if science progressed to the point where such a change could be reliably *forecast*, then emitters would begin planning on higher permit prices as far in advance as the forecast could be made. Of course if science never permits such forecasts then no policy will anticipate them, but my suggestion will at least ensure a rapid, automatic response. If no such abrupt change ever takes place, then the feedback rule would avoid imposing unnecessarily the costs associated with trying to prevent it.

The chief objection to a feedback-based approach is that it seems to be backward-looking, taking action only after the problem has been revealed, yet warming may not happen right away in response to greenhouse gases. However, according to the IPCC, the tropical troposphere (in models) adjusts rapidly to changes in greenhouse gas changes, making it an appropriate metric for guiding changes in the cap. Also, investors and firms are forward-looking: they make decisions now based on expected market conditions years ahead. By tying the carbon dioxide emissions control policy to contemporary atmospheric conditions, it requires firms to take account of the best available climatic data and warming forecasts when making major investment decisions, which is precisely the goal of any long term policy.

Finally, another potential objection to the feedback approach is the fear that emissions today might commit us to warming a long way ahead, i.e. 20 or 30 years. However, those making this objection are asking us to trust climate models over actual data. The data show that models have demonstrated insufficient fidelity to the relevant data over the past 30 years to merit trusting them as the basis for a permanent commitment to reducing American energy consumption over the next 30 years. They consistently over-estimate tropospheric warming and project a spatial pattern that does not match the data. A feedback rule like the one I propose takes the models seriously enough to admit the possibility that greenhouse gases may need to be reduced in the coming years, but hedges that bet by ensuring the policy only gets stringent to the extent the problem is revealed to be serious.

Yours truly,

Ross McKitrick
Associate Professor of Economics