Hearing on The Case for Climate Change Action

Wednesday, October 1 2003 - 9:30 AM - SR- 253

The Testimony of
The Honorable John McCain
United States Senator, (R-AZ)

Welcome. Today's hearing will be the third in a serious of hearings this Committee has held this year on the very critical topic of global climate change–an issue of world-wide importance.

• The National Academy of Sciences (NAS) has reported that, "Greenhouse gases are accumulating in the Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Temperatures are, in fact, rising. The changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability."

• While the NAS statement allows that factors other than human activity may affect temperatures, there is broad scientific consensus that global warming is occurring, that human activity is causing it, and that its consequences are extremely serious. While these consequences are alarming to think about, and politicians are naturally inclined to postpone tough choices, no excuse for inaction on this issue is acceptable.

• While Congress and the Administration continue to expend their efforts on justifying our inaction, many countries have already recognized the scientific consensus, some states have joined together to address the problem, and domestic businesses are taking their own actions to respond to global climate change. National leadership on this critical issue is long overdue.

• Earlier this year, Senator Lieberman and I introduced S. 139, the Climate Stewardship Act of 2003, which proposes to establish a mandatory carbon dioxide reduction program along with an emissions trading system. We believe that a market-based approach, combined with mandatory caps and federal oversight, offers the best way for the nation to respond to a growing global environmental threat.

• We requested the Energy Information Administration (EIA) and the Environmental Protection Agency (EPA) to conduct analyses of our climate change proposal. While EIA responded to our request, EPA did not. Based on the EIA's analysis as well as an independent analysis performed by the Massachusetts Institute of Technology and the Tellus Institute, we intend to offer a modified approach when the Senate finally debates our climate change legislation, which we expect to occur later this month.

• Specifically, Senator Lieberman and I will offer a substitute amendment which will, among other things, eliminate the second target date for reductions of greenhouse gases. It also would require the affected sectors to reduce their greenhouse emissions to the year

2000 levels by the year 2010, which is approximately 1.5 percent below today's levels. The bill, as introduced, would have required additional reductions by the year 2016.

- By modifying the bill, we expect to build additional momentum for the measure in the Senate, and we have insisted on and secured an agreement for a vote on the measure, a vote that must take place in order for constituents to know where their Senator stands on one of the most important environmental issues of our time.

- We have a number of witnesses with us today to help further inform the Committee about the results of leading edge scientific research, discuss actions being taken by industry in response to this growing world-wide concern, and public reaction to recent environmental reports on climate change. We are also joined today by a representative from the European Union (EU) to discuss the EU's efforts to develop a "cap and trade" system.

- I welcome our witnesses here today and look forward to their testimony.

The Testimony of
Dr. Antonio Busalacchi, Jr.
Chair of the Climate Research Committee, Board on Atmospheric Science and Climate, National Research Council

Good morning. Thank you very much for this opportunity to testify. I am Dr. Tony Busalacchi, a professor at the University of Maryland and I serve as the chair of The National Academies' Climate Research Committee. I will use my time this morning to summarize what most scientists agree to be true about change in the Earth's climate.

Understanding climate and whether it is changing, and why, is one of the most crucial questions facing humankind in the twenty-first century. This question is the subject of much scientific research and, of course, policy debate, since the economic and environmental implications could be large. The National Academies have produced a number of reports focused on understanding climate in recent years and my testimony draws heavily from two of these: a February 2003 report that gives input to the Administration's draft US Climate Change Science Program Strategic Plan (NRC 2003) and a 2001 report called "Climate Change Science" that was done at the request of the White House (NRC 2001). The latter report answered a series of specific questions designed to identify areas in climate change science where there are the greatest certainties and uncertainties. If you haven't read this report, it is an excellent summary (only 25 pages long) written in very accessible language.

As is explained in "Climate Change Science," there is wide scientific consensus that climate is indeed changing. Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Our confidence in this conclusion is higher today than it was ten, or even five years ago, but uncertainty remains because there is a level of natural variability inherent in the climate system on time scales of decades to centuries that can be difficult to interpret with precision because we gather this evidence from sparse observations, numerical models, and proxy records such as ice cores and tree rings. Despite the uncertainties, however, there is widespread agreement that the observed warming is real and particularly strong within the past twenty years.

As the report further explains, human-induced warming and associated sea level rises are expected to continue through the 21st century. Computer model simulations and basic physical reasoning show that there will be secondary effects from these changes. These include increases in rainfall rates and increased susceptibility of semi-arid regions to drought. The impacts of these changes will depend on the magnitude of the warming and the rate with which it occurs.

A diverse array of evidence supports the view that global air temperatures are warming. Instrumental records from land stations and ships indicate that global mean surface air temperature warmed about 0.4-0.8 degrees C (0.7-1.5 degrees F) during the 20th century. The warming trend is spatially widespread and is consistent with the global retreat of mountain glaciers, reductions in snow-cover extent, the earlier spring melting of ice on rivers and lakes, the accelerated rate of rise of sea level during the 20th century relative to the past few thousands years and the increase in upper-air water vapor and rainfall rates over many regions. A lengthening of the growing season also has been documented in many areas, along with an earlier plant flowering season and earlier arrival and breeding of migratory birds. Some species of plants, insects, birds and fish have shifted toward higher latitudes or higher elevations, often together with associated changes in disease vectors. The ocean, which represents the largest reservoir of heat in the climate system, has warmed by about 0.05 degrees C (0.09 degrees F) averaged over the layer extending from the surface down to 10,000 feet, since the 1950s.

It has been said that the Arctic will be the “canary in the coal mine” where the effects of global warming will be felt first and with the greatest magnitude. Analysis of recently declassified data from US and Russian submarines indicates that sea ice in the central Arctic has thinned since the 1970s, and satellite data indicate a 10-15 percent decrease in summer sea ice concentration over the Arctic as a whole. Satellite measurements also indicate that the time between the onset of sea-ice melting and freeze-up has increased significantly from 1978 through 1996, and the number of ice-free days have increased over much of the Arctic Ocean. A decline of about 10 percent in spring and summer continental snow cover extent over the past few decades also has been observed. Looked at in total, the evidence paints a reasonably coherent picture of change, but the conclusion that the cause is greenhouse warning is still open to debate; many of the records are either short, of uncertain quality, or provide limited special coverage.

As you may have seen in the press, a large ice shelf recently broke up along the coast of northeast Canada’s Ellesmere Island, followed by the drainage of an ice-dammed lake that had built up behind it (Disraeli Fiord). The Ward Hunt Ice Shelf was the largest remaining piece of an ice shelf that once, a century ago, rimmed the entire northern coast of Ellesmere Island. I have not studied this particular incident, nor has the Academy, but researchers working at the site had documented reductions in the freshwater volume of the lake accompanied by a rise in mean annual air temperature and have stated that they believe this change can be attributed to global warming. Other scientists have been more cautious, noting that many of the changes being seen in the Arctic could have more to do with long-term world climate patterns than with the release of carbon dioxide and other greenhouse gases. Still, atmospheric chemist and National Academy of Sciences member Ralph J. Cicerone of the University of California at Irvine was quoted in the Washington Post article on the ice-shelf breakup as saying: "But even though this ice melt and permafrost thawing [probably happened] too fast to be due to global warming, this is [a] prototype of what we should expect after the next few decades. … This is a good dress rehearsal for the kinds of things we could see later."

Some of the changes being experienced at high latitudes are believed to be reflections of changes in wintertime wind patterns rather than a direct consequence of global warming per se. It is important to note that the rate of warming has not been uniform over the 20th century. Much of the warming occurred prior to 1940 and during the past few decades. The Northern Hemisphere as a whole experienced a slight cooling from 1946-1975, and the cooling during that period was quite marked over the eastern United States. The cause of this hiatus in the warming is still under debate. One possible cause might be the buildup of sulfate aerosols due to the widespread burning of high sulfur coal during the middle of the century followed by a decline; it is also possible that at least part of the rapid warming of the Northern Hemisphere during the first part of the 20th century and the subsequent cooling were of natural origin – a remote response to changes in the oceanic circulation, or variations in the frequency of major volcanic emissions or in solar luminosity.

The role that human activities have played in causing these climate changes has been a subject of debate and research for more than a decade. There is no doubt that humans have modified the abundances of key greenhouse gases in the atmosphere, in particular carbon dioxide, methane, nitrous oxide, and tropospheric ozone. These gases are at their highest recorded levels. In fact, the ice-core records of carbon dioxide and methane show their twentieth century atmospheric abundances to be significantly larger than at any period over the past 400,000 years. The increase in these greenhouse gases is primarily due to fossil fuel combustion, agriculture, and land-use changes. Recent research advances have led to widespread acceptance that the human-induced increase in greenhouse gas abundances is responsible for a significant portion of the observed climate changes. The precise size of that portion is difficult to quantify against the backdrop of natural variability and climate forcing uncertainties.

Because the Earth system responds so slowly to changes in greenhouse gas levels, and because altering established energy-use practices is difficult, changes and impacts attributable to these factors will continue during the twenty-first century and beyond. Current models indicate a large potential range for future climates, with global mean surface temperature warming by 1.4 to 5.8ºC (2.5 to 10.4 oF) by 2100 (IPCC, 2001).

Given increasing evidence of how humans have modified the Earth's climate over the last century, it is imperative for the nation to continue directing resources toward better observing, modeling, and understanding of what form future changes in climate and climate variability may take, the potential positive and negative impacts of these changes on humans and ecosystems, and how society can best mitigate or adapt to these changes.

Thank you for this opportunity to talk about climate change. This is a problem that affects us all, and a problem the scientific community does not shy away from in terms of its responsibility to provide objective scientific assessment in support of sound policy decisions. I'd be happy to take any questions.

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The Testimony of
Mr. Ethan J. Podell
President, Orbis Energy, LLC

Mr. Chairman and distinguished Members of the Senate,

I am grateful for the invitation to address the Committee and to share my perspective as a businessman who has tried to get corporate America to take voluntary action on climate change.

My name is Ethan Podell. I'm the President of Orbis Energy Advisors, a finance and consulting firm focused on the business of climate change and renewable energy. I am also here today as a representative of E2—Environmental Entrepreneurs--- a national group of professionals and business people who believe in protecting the environment while building economic prosperity. E2 has over 400 members in 16 states who have been involved in financing and founding more than 800 companies, which created over 400,000 jobs. E2 members currently represent more than $20 billion in private equity capital available for investment into new companies.

After a 20 year career as a media entrepreneur, I've spent the better part of the past two years trying to get corporate America to understand---and more importantly to take some meaningful action to address-----this enormous problem looming before us…..global climate change. My conclusion from this experience is that it is essential to enact mandatory limits on greenhouse gas emissions as provided for by S. 139.

I consulted on strategy and business development for Cantor Fitzgerald's greenhouse gas trading unit. From March through August of this year, I was the senior vice president for sales and marketing for the Chicago Climate Exchange. As you may know, the Chicago Climate Exchange is the first voluntary, greenhouse gas cap and trade program in the U.S. My principal role at the Exchange was to recruit corporate clients willing to commit to a modest, pilot program requiring minimal reductions in their greenhouse gas emissions. I'm here to tell you today that there is very little evidence that corporate America has any real interest in participating in a voluntary greenhouse gas reduction trading program.

The Chicago Climate Exchange is a terrific idea and an innovative institution of the first order. It seeks to prove the concept that a voluntary, greenhouse gas emissions reduction program using a cap-and-trade system can be effective with the American business community. The Exchange is designed as a 4-year pilot program, running from now through 2006, so that companies which join the program are making a limited time commitment. And Exchange members are also making a very limited commitment to reduce their greenhouse gas emissions, as the reduction targets set by the Exchange are extremely modest. Those reductions are 1% below baseline in 2003, rising to 4% below baseline in 2006.

The Chicago Climate Exchange was designed over a number of years with the active participation of leading companies from many sectors of American business. Notwithstanding the modest reduction targets and other incentives embedded in the rules of the Exchange, which are designed to make for a very slow and non-threatening game of softball, there are—so far at least-----very few takers in the corporate world. As of last week, only about 20 companies in the U.S. had agreed to participate in the Chicago Climate Exchange. These companies are responsible for about 3 or 4% of the total U.S. greenhouse gas emissions. If you do the math and apply the 1% per year emissions reduction required of members of the Chicago Climate Exchange against the 4% of total U.S. emissions which these companies represent, what we end up with is a very small drop removed from a very large bucket. This bucket has 10,000 drops; the current members of the Chicago Climate Exchange will remove 4 of these 10,000 drops this year and 16 in the year 2006.

As we have seen with the acid rain program, cap-and-trade can accomplish real environmental goals at modest cost when coupled with a mandatory set of targets. However, without regulation and governmentally-imposed sanctions, the early evidence, at least, is that the American business community is not very interested in a voluntary, greenhouse gas cap and trade program.

Over the past six months, I've spoken or met with more than 250 companies, mostly in the Fortune 500, but smaller private businesses as well, about why they should join the

Chicago Climate Exchange. I've also marketed the Exchange to municipalities, universities and state governments.

For a cap and trade system to work, you really need only three things: 1). a target or cap representing some reduced level of emissions when measured against the past; 2). a group of participants that will reduce their emissions below the target and have excess reduction credits to sell; and 3). a group who will miss the target and need to buy credits to be in compliance with the rules of the game.

What I've seen in marketing the Chicago Climate Exchange is that there are very few companies in this country willing to commit to buy emission credits to be in compliance with a voluntary greenhouse gas reduction program.

The companies which are willing to participate in a voluntary can-and-trade program are those that see carbon trading as a way to make some money by selling excess credits, and a way to make a statement---really a gesture--- about their environmental awareness. For these companies, the ones which will be sellers of emission reduction credits, participating in a program such as the Chicago Climate Exchange is largely a risk-free, money-making opportunity.

The companies we really need to join a carbon cap-and-trade program, the large emitters of greenhouse gases, those who will end up as buyers of emission reduction credits---- the utilities, the oil/gas/petrochemical companies, the cement makers, the truckers and railroads ---these companies are not yet prepared to join a voluntary cap-and-trade program.

The large carbon emitters listen attentively to all the arguments: that regulation will happen sooner or later so they should get in early and learn ahead of their competitors; that Wall Street and other stakeholders are increasingly concerned about the link between the company's carbon liabilities and its balance sheet; that the company's overseas operations are as a practical matter subject to greenhouse gas reductions under the Kyoto Protocol or other emerging international regulations whether or not the U.S. government participates along with the international community.….Yes, they listen, some even agree to gather data on their historic levels of emission, but very few companies are prepared to reduce these emissions if it will cost them any money.

Yes, it's true that there is nothing to prevent a voluntary system from working here….other than the absence of volunteers. And that is precisely what we have----the absence of volunteers.

And, why after all, should any one American company agree to take the lead on voluntary greenhouse gas reductions? Where are their competitors on this issue? Why be a pioneer when it will just cost them money, threaten their market share, and worst of all, even if they agree to join a voluntary reduction program, where's the assurance that Washington will recognize their early participation in a voluntary program, and not later create legislation which raises the bar and penalizes the early movers? The image here is that pioneers were the ones who ended up with arrows in their backs. Long-term thinking about the environment being in short supply in corporate America, our business leaders generally ignore, or forget, the fact that many pioneers ended up, not with arrows in their backs, but as the owners of very valuable real estate.

In the absence of rules and clear guidelines, the field evidence I have is that most American businesses would prefer to sit this one out from the sidelines. Washington needs to provide firm rules and regulations if you expect corporate America to respond. When it comes to climate change, voluntary action in the real world means hardly any action at all. As S. 139 recognizes, a cap-and-trade system is likely to be cost-effective in reducing greenhouse gas emissions, provided it is a mandatory system.

A mandatory carbon cap-and-trade program, such as S. 139, will cause some disruption, some adjustments in everyone’s business-as-usual behavior, and it is not--- at least not in the short term---without some costs. However, the costs are regularly exaggerated, and the benefits often ignored by the business community. A recent MIT study on S 139 showed that its enactment would affect household purchasing power by less than 1/10th of 1 %. The gains in energy efficiency and in technological innovation which will follow once we start to constrain carbon emissions in this country will far outweigh any of the short term burdens which will be imposed upon the business community. And over time, the cost of compliance will turn into real and large levels of cost savings. A recent analysis of S 139 by the Tellus Institute shows that as this legislation is implemented over time, it will ultimately yield net cost savings to American consumers of some $50 billion per year.

Real, meaningful action on climate change is not an academic or theoretical issue anymore. A March, 2003 Gallup poll found that 75% of Americans support “mandatory controls on carbon dioxide and other greenhouse gas emissions.” In a recent University of Oregon poll, some 80% of Americans said that climate change is a real problem and one for which the business community should take direct responsibility.

Many in the business community understand the magnitude of global warming. They are waiting for our political leadership to devise the necessary rules and policies. Without regulation, the business community will stay in its comfort zone, and continue to wait and delay action on this critical world issue.

Scientific understanding today of climate change is clear and certain enough to point public policy in one direction and one direction only. We do not really need more research on the relationship between clouds and climate change before we take action. We do not need to wait a decade for energy research to magically deliver a silver bullet, which will never arrive unless the private sector has a clear incentive to invest in innovative solutions. No, what we need is to take action now to reduce our greenhouse gas emissions. We are kidding ourselves if we think that a plea for voluntary action to reduce greenhouse gas emissions in the U.S. will accomplish anything.

Climate change is, as the World Business Council said not too long ago, the single biggest issue facing the world business community. The American business community has a special responsibility here to participate fully and actively in finding the right solution. We emit 25% of the world's greenhouse gases. S. 139 is a path-breaking, innovative step, a bold effort to take America in the right direction on a critical issue for the future of our world. Only with a mandatory set of greenhouse gas emission targets will we make any meaningful progress in winning this crucial war with carbon.

Thank you.

Ethan J. Podell

Trained as a lawyer, Ethan Podell spent over twenty years as an entrepreneur in television programming and distribution. He co-founded and built two private media enterprises, active in both the U.S. and European markets. Both companies—Orbis Communications and Orbis Entertainment---were eventually sold to publicly-traded entertainment companies. Podell has served as chief financial officer (Orbis Communications Inc.) and chief executive officer of Orbis Entertainment Company (later All American Orbis), where he was responsible for client relationships, program creation and sales. Podell began his career in 1978 as a lawyer for O'Melveny & Myers in Los Angeles, and then worked in legal and business affairs for CBS and HBO, before starting his first company

Several years ago Ethan Podell began an entirely new career focused on environmental issues, in particular business opportunities connected with climate change and greenhouse gas trading. As a consultant, Podell developed a marketing strategy for greenhouse gas trading in the U.S. (for a unit of Cantor Fitzgerald), and recruited clients for the first voluntary greenhouse gas trading program in the U.S. (Chicago Climate Exchange), where he was senior vice president for sales and marketing. Podell recently founded Orbis Energy Advisors Inc., a finance and consulting company focused on the business of climate change and renewable energy.

Podell is active in E2, a national community of professionals and business people promoting environmental protection while building economic prosperity. He has also done pro bono work as a lawyer and business adviser for the Rainforest Alliance and The Nature Conservancy.

Ethan Podell earned his undergraduate degree at Brown University (B.A. 1974) where he was elected to Phi Beta Kappa. He holds a Masters from the University of Chicago (Committee on Social Thought, 1975) and a law degree from Northwestern University (1978), where he was on the editorial board of the Law Review.

Podell is a member of the State Bar of California, and currently resides in New York.

Ethan J. Podell President Orbis Energy Advisors Inc.

Hearing on "The Case for Climate Change Action"
October 1, 2003

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Introduction and Personal Perspective. If I may indulge in a personal note at the outset: it is a pleasure to appear again in front of both Senators McCain and Lieberman on climate change issues, having had that honor on several occasions since the mid-1980s with Senator McCain and the mid-1990s with Senator Lieberman. As these hearings today are about the "case for action" on climate change based on sound science assessment, I will try to emphasize aspects of the science of climate change less exhaustively covered by other witnesses, such as Dr. Tom Wigley of the National Center for Atmospheric Research, whose testimony on climate change science I fully associate myself with. Instead, I will focus more on climate change impacts. The problem was well-stated by Senator Lieberman when I commented to the Senate Environment and Publics Works Committee, chaired by the late Senator Chaffee, in July 1997. At that time, Senator Lieberman said:

> Changes in climate have major implications for human health, water resources, food supplies, infectious diseases, forests, fisheries, wildlife populations, urban infrastructure, and flood plain and coastal developments in the United States. Although uncertainties remain about where, when, and how much climate might change as a result of human activities, the changes—when they happen—may have severe impacts on many sectors of the U.S. economy and on the environment. These are serious risks that we must start considering (p. 15).

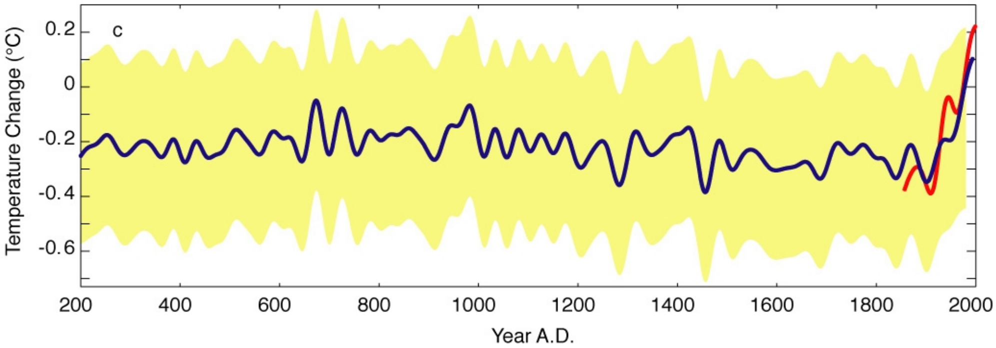
This statement is equally valid today and can be further supported by substantially more scientific studies pointing out potentially serious climate impacts. I will briefly review some of these and put them in the context of climate change cost-benefit analyses. But first, a brief statement about the climate change science itself.

While testifying to this Committee on May 8, 1989—when Senator McCain was a member of the Committee—I recall a discussion about the problem of uncertainties surrounding climate change and the question of how long we should wait before taking action. Some debaters had asserted that there wasn't enough direct evidence of human-induced climate change for strong policy actions. In response to Senators from this committee on that point, I agreed that "Most of our confidence that the future will change is based on literally millions and millions of observations which tell us about the heat trapping properties of gases, not based so much on the performance of the planet this century. If we insist on waiting for the planet to catch up to what we expect it to do, it is another 10 to 20 years to prove that beyond doubt" (p.150).

Well, it is now 14 years since I said that. I believe the work of the Intergovernmental Panel on Climate Change (IPCC), the U.S. National Academy of Sciences (NAS), and others has amply demonstrated that, indeed, nature has "caught up" with our expectations of warming and in fact added a few surprises like rapid changes in polar regions and devastating heat-wave-induced deaths, even in modern, highly developed countries, with the more than 15,000 mortalities occurring in France this summer as a result of the extreme heat serving as a prime example.

Surface warming trends are solidly grounded in observational science and consistent with human-induced pressures. It is scientifically well established that the Earth's surface air temperature has warmed significantly, by about 0.6 ° Celsius (C) since 1860, and that an upward trend can be clearly discerned by plotting historical temperatures. Such a graph would show a rapid rise in temperature at the end of the twentieth century. This is supported by the fact that all but three of the ten warmest years on record occurred during the 1990s. But what has been learned only in the past five years is that this unusual warmth in recent years is not just an anomaly in temperature records of the last 140 years, but the past 2000, as Figure 1 displays.

Figure 1. 2,000-year reconstruction of global temperature changes in degrees Celsius



The blue line represents the temperature reconstruction, with 95% confidence band shown in yellow and the instrumental record in red. Notice that the last several decades of the 20th century exceed the range of temperatures over the past 2000 years. (Source: Mann and Jones, 2003.)

The probability that the radical upward swing in temperature at the tail end of the 20th century is just a natural quirk of nature—as some "contrarians" and their political supporters contend—is exceedingly low. If, as some assert, "the sun did it", then what was the sun doing over the previous 2 millennia? It is rather perverse to expect such radical behavior from the sun just now, at the same time that we have clear evidence of human-induced pressures coincident with the warming. While the possibility (at some low probability) that natural factors are responsible for the unusual warmth of the Earth's surface at the end of the 20th century cannot be ruled out completely, a much more likely explanation is that the warming is the result of a mix of natural and human-induced (anthropogenic) factors. While this alone is cause for worry, more disquieting still are climate change projections for the 21st century, especially if we assume that greenhouse gas emissions follow a business-as-usual path.

It is for these reasons that I express my personal satisfaction for having, over the past two decades, had the opportunity to testify to the Senators currently leading this effort to establish a meaningful climate change policy for the United States that will actually result in emissions reductions. In my personal opinion, it is essential that we get on with the job of providing (mandatory) incentives to push the amazing industrial and intellectual capacity of our country to fashion cost-effective solutions. I thank the Senators for having pursued this issue over the long term.

As mentioned, nature has cooperated with theory in the past few decades, as evidenced by the record warming. In addition, it is well-established that human activities have caused increases in radiative forcing, with radiative forcing defined as a change in the balance between the radiation coming into and going out of the surface-atmosphere system. In the past few centuries, atmospheric carbon dioxide has increased by more than 30 percent, and virtually all climatologists agree that the cause is human activities, and the burning of fossil fuels in particular.

Despite the many well-established aspects of the science of climate change (e.g., anthropogenic forcing of global warming), other aspects (e.g., specific regional changes) are still being vigorously debated. In fact, the climate change debate is characterized by deep uncertainty, which results from factors such as lack of information, disagreement about what is known or even knowable, linguistic imprecision, statistical variation, measurement error, approximation, subjective judgment, and disagreement about structural models, among others (see Moss and Schneider, 2000). These problems are compounded by the global scale of climate change, which produces varying impacts at local scales, long time lags between forcing and its corresponding responses**,** very long-term climate variability that exceeds the length of most instrumental records, and the impossibility of before-the-fact experimental controls or empirical observations (i.e., there is no experimental or empirical observation set for the climate of, say, 2050 AD, meaning all our future inferences cannot be wholly “objective,” data-based assessments — at least not until 2050 rolls around). Moreover, climate change is not just a scientific topic but also a matter of public and political debate, and degrees of uncertainty may be played up or down (and further confused, whatever the case) by stakeholders in that debate.

Can We Define “Dangerous” Climate Change? Article 2 of the UN Framework Convention on Climate Change (UNFCCC) states that: “The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”. The Framework Convention on Climate Change further suggests that:

"Such a level should be achieved within a time frame sufficient

- to allow ecosystems to adapt naturally to climate change,
- to ensure that food production is not threatened and
- to enable economic development to proceed in a sustainable manner."

Thus, the term "dangerous anthropogenic interference" may be defined or characterized in terms of the consequences (or impacts) of climate change outcomes, which can be related to the levels and rates of change of climate parameters. These parameters will, in turn, be determined by the evolution of emissions and consequent atmospheric greenhouse gas concentrations. Evaluating the consequences of climate change outcomes to determine those that may be considered "dangerous" is a complex undertaking, involving substantial uncertainties as well as value judgments. In this context, the role of scientists is to assess the literature with a view to providing information that is policy-relevant, without being policy prescriptive.

Climate Sensitivity and Climate Scenarios to 2100 and Beyond. By how much will humans and natural changes in the Earth each contribute to future climate disturbance? The IPCC has attempted to tackle this controversial question in its Special Report on Emission Scenarios (SRES), which contains a range of possible future climate scenarios based on different assumptions regarding economic growth, technological developments, and population growth, arguably the three most critical determinants of future climate change. Together, the fan of possible climate scenarios and the probability distributions of possible climate sensitivities determine what policy makers often want to know—by how much will it warm in, say, 2100 (or any other time), depending on what policies we choose to change emissions scenarios (e.g., Schneider, 2002).

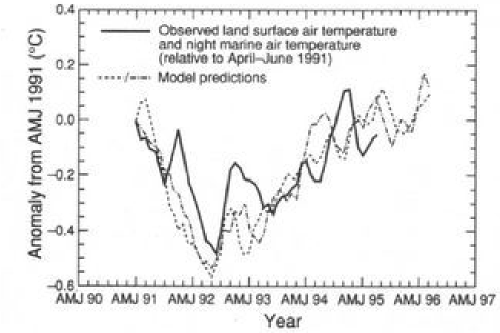
The SRES scenarios and other climate change projections depend on detailed modeling. The most typical way scientists codify knowledge is by constructing models made up of the many subcomponents of the climate system that reflect our best understanding of each subsystem. The most comprehensive models of atmospheric conditions are three-dimensional, time-dependent simulators known as general circulation models (GCMs). Because of the complexity and computational costs of GCMs, simpler models are often constructed to explore the sensitivity of outcomes to plausible alternative assumptions (e.g., Wigley's, testimony to this session). The system model as a whole cannot be directly tested before the fact — that is, before the future arrives — but it can be verified against historical situations that resemble what we believe will be analogous to what will occur in the future (see "Model Validation" below).

While modeling has become both more complex and more accurate as computing abilities have advanced and more is understood about the climate problem, scientists still have to deal with an enormous amount of uncertainty, as mentioned above. In modeling, a major uncertainty is climate sensitivity, the amount by which the global mean surface air temperature will increase for a doubling of CO_2 concentrations from pre-industrial levels. Many scientists have done extensive modeling and observational research on this subject over the past 20 years, and most agree that climate sensitivity probably falls somewhere within the IPCC's range of 1.5-4.5 ^{o}C. However, that old consensus is changing, as several recent studies (e.g., Andronova and Schlesinger, 2001; Forrest et al, 2001) have estimated that climate sensitivity could be an alarming 6 ^{o}C or higher. (To give a sense of the magnitude, a 5-7 ^{o}C ***drop*** in temperature is what separates Earth's present climate from an ice age.)

Model Validation. In the presence of so much uncertainty, how can modelers be more confident in their model results? How do they know that they have taken into account all economically, ecologically, and/or climatologically significant processes, and that they have satisfactorily "parameterized" processes whose size scales are below that of their models' grid cells? The answer lies in a variety of model validation techniques, most of which involve evaluating a model's ability to reproduce — in the case of climate models — known climatic conditions in response to known forcings.

Volcanic eruptions are one good form of model validation. Major volcanic eruptions inject so much sulfuric acid haze and other dust into the stratosphere that they exert a global cooling influence that lasts several years. Such eruptions occur somewhat randomly, but there is typically one every decade or so, and they constitute natural "experiments" that can be used to test climate models. The last major volcanic eruption, of the Philippine volcano Mt. Pinatubo in 1991, was forecast by a number of climate modeling groups to cool the planet by several tenths of a degree Celsius. That is indeed what happened.

Figure 2. Predicted and observed changes in global temperature after the 1991 eruption of Mt. Pi



Solid curve is derived from measured air temperatures over land and ocean surfaces. Broken curves represent climate model runs with slightly different initial conditions. In both cases the models included the effect of dust injected into the atmosphere by the volcanic eruptions. (Source: Hansen et al, 1996.)

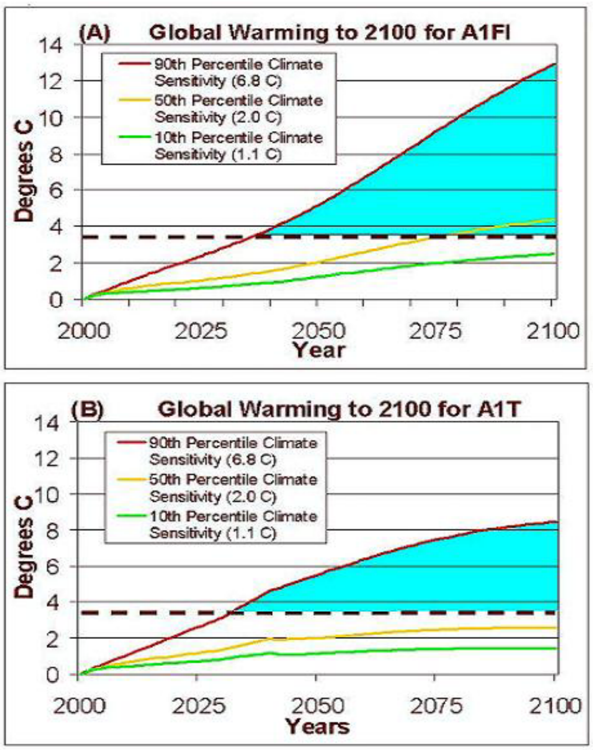
Figure 2 shows a comparison between actual global temperature variations and those predicted by a climate model for a period of five years following the Mt. Pinatubo eruption. Now, a drop in temperature of a few tenths of a degree Celsius is small enough that the observed variation just could be an unusual natural fluctuation. However, earlier eruptions, including El Chichón in 1983 and Mt. Agung in 1963, were also followed by a marked global cooling of several tenths of a degree Celsius. Studying the climatic effects from a number of volcanic eruptions shows a clear and obvious correlation between major eruptions and subsequent global cooling. Furthermore, a very simple calculation shows that the negative forcing produced by volcanic dusts of several watts per square meter is consistent with the magnitude of cooling following major volcanic eruptions. Viewed in light of these data, the graph above suggests that climate models do a reasonably good job of reproducing the large-scale climatic effects of volcanic eruptions over a time scale of a few years.

Seasonality provides another natural experiment for testing climate models. Winter weather typically averages some fifteen degrees Celsius colder than summer weather in the Northern Hemisphere and five degrees Celsius colder in the Southern Hemisphere. (The Southern Hemisphere variation is lower because a much larger portion of that hemisphere is water, whose high heat capacity moderates seasonal temperature variations.) Climate models do an excellent job reproducing the timing and magnitude of these seasonal temperature variations, although the absolute temperatures they predict may be off by several degrees in some regions of the world. However, the models are less good at reproducing other climatic variations, especially those involving precipitation and other aspects of the hydrological cycle. Of course, being able to reproduce the seasonal temperature cycle alone — since it comes full circle in only one year — does not guarantee that a model will accurately describe the climate variations resulting from other driving factors (such as increasing anthropogenic greenhouse gas concentrations) that will likely occur over decades or centuries. On the other hand, the fact that models do so well with seasonal variations is an assurance that the models' climate sensitivity is unlikely to be off by a factor of 5 - 10, as some contrarians assert.

Joint Probability Estimation. The combined effects of uncertainties in emissions and uncertainties in climate sensitivity are also known as a “joint probability” (i.e., sensitivity and emissions varied jointly). How do we approach this question of the joint probability of temperature rise to 2100 *and* crossing some “dangerous” warming threshold, to use the language of the UNFCCC—which, by the way, was signed by President Bush in 1992 and ratified by the Senate. Instead of using two probability distributions, an analyst could pick a high, medium, and low range for each factor and plot the results, as I will demonstrate. For example, a glance at Andronova and Schlesinger’s (2001) calculations shows that the 10 percentile value for climate sensitivity is 1.1 ^{o}C for a doubling of CO_2 (i.e., 4 W/m^2 of radiative forcing). 1.1 ^{o}C is, of course, below the IPCC's lower limit climate sensitivity value of 1.5 ^{o}C. However, this merely means that there is a 10 percent chance climate sensitivity will be 1.1 ^{o}C or less — that is, a 90% chance climate sensitivity will be 1.1 ^{o}C or *higher*. The 50th percentile result — that is, the value that climate sensitivity is as likely to be above as below — is 2.0 ^{o}C. The 90th percentile value for climate sensitivity from Andronova and Schlesinger (2001) is 6.8 ^{o}C, meaning there is a 90% chance climate sensitivity is 6.8 ^{o}C or less, but there is still a very uncomfortable 10% chance it is even higher than 6.8 ^{o}C — a value well above the 4.5 ^{o}C figure that marks the top of the IPCC's range. Using these three values to represent a high, medium, and low climate sensitivity, we can produce three alternate projections of temperature over time, once an emissions scenario is decided on.

In Schneider (2003), the three climate sensitivities just explained were combined with two SRES storylines: A1FI, the very high emissions, fossil fuel-intensive scenario; and A1T, the high technological innovation scenario, in which development and deployment of advanced technologies dramatically reduces the long-term emissions. This comparison pair almost brackets the high and low ends of the 6 SRES representative scenarios' range of cumulative emissions to 2100, and since both are for the "A1 world," the only major difference between them is the technology component. This component should be viewed as a "policy lever" that could be activated through the implementation of policies to encourage decarbonization, for example—like the bill before this committee. Therefore, studying how different the evolution of projected climate is to 2100 for the two different scenarios is a very instructive exercise and can help in exploring the different likelihoods of crossing "dangerous" warming thresholds.

Figure 3. Three climate sensitivities and two scenarios (source: Schneider, 2003)



As noted in Figure 3 above, the three climate sensitivities — 10th, 50th and 90th percentiles — designated by Andronova and Schlesinger (2001) are combined with the radiative forcings for the A1FI and A1T scenarios laid out in the SRES. The dashed horizontal lines in both graphs represent the 3.5 °C cut-off — a very conservative number picked by me as the threshold value for "dangerous" climate change — and the blue shaded area marks the extent to which each temperature change scenario exceeds that 3.5 °C threshold. As shown, these scenarios produce similar projections of warming for the first several decades of the 21st century, but diverge considerably— especially in the high-sensitivity 90th percentile case — after mid-century. The 50th and 90th percentile A1FI cases both exceed the threshold of 3.5 °C warming before 2100, and the area shaded in blue is much more dramatic in the fossil-intensive scenario than the technological innovation scenario. In fact, at 2100, when the A1T curves are stabilizing, the A1FI curves are still upwardly sloped — implying even greater warming in the 22nd century. In order to fully assess "dangerous" climate change potential, simulations that cover well over 100 years will be necessary, since it is widely considered that warming above a few degrees Celsius is likely to be much more harmful than changes below a few degrees (see Figure 4 below).

How Long is a "Long View"? The most striking features of both scenarios in Figure 3 are the top (red) lines, which rise very steeply above the two lines below them. That is because of the peculiar shape of the probability density function for climate sensitivity in Andronova and Schlesinger (2001). [For those concerned with the technical details, that is because the probability density function has a long tail on the right-hand side, representing the possibility that aerosols have been holding back not-yet-realized warming and the rise in temperature could be much higher than currently expected.] Also striking is that both the 10th and 50th percentile results for both the A1FI and A1T scenarios don't differ much in 2050, but then diverge considerably by 2100. This has led some to declare (erroneously, in my view) that there is very little difference in climate change across scenarios or even among different climate models with different sensitivities. This is clearly wrong, for although both A1FI and A1T have emissions, and thus CO_2 concentration, projections that are not very different for the first several decades of the 21st century, they diverge after 2050, as does the temperature response. For the 90th percentile results, both the A1FI and the A1T temperature projections exceed the "dangerous" threshold of 3.5 °C at roughly the same time (around 2040), but the A1FI warming not only goes on to outstrip the A1T warming, but is still steeply sloped at 2100, implying warming beyond 13 °C in the 22nd century, which would undoubtedly leave a dramatic legacy of environmental damage for distant posterity and great ecological stress for nature.

Figure 3 shows, via a small number of curves (6 in all), the probability of temperature changes over time for three climate sensitivity probabilities, but it does not give probabilities for the emissions scenarios themselves; only two are used to "bracket uncertainty," and thus no joint probability can be gleaned from this exercise. This is the next step that needs to be taken by the research community. An MIT integrated assessment group (Webster et al, 2003) has already attempted to fashion a probability distribution for future climate using a series of different models and expert judgments. Like other assessments, their work also suggests a wide range of possibilities, with some representing quite "dangerous" potential outcomes. That approach, I predict, will be the wave of the future in such analyses, but given the heavy model-dependence of any such results, individual "answers" will remain controversial and assumption-bound for a considerable time to come.

The likelihood of threshold-crossing is quite sensitive to the particular selection of scenarios and climate sensitivities used. However, in these bracketing studies, the probability of crossing “dangerous” thresholds of climate change is typically around ten percent—a risk society will have to weigh against the costs of climate mitigation activities. As will be discussed shortly, that is a high risk indeed.

If conventional economic discounting were applied, some present-day “rationalists” might argue that the present value of damages postponed for a century or so is virtually nil. But what if our behavior were to trigger irreversible changes in sea levels and ocean currents or the extinction of species (on generational time scales)? Is it fair to future generations for us to leave them the simultaneous legacy of more wealth and severe ecosystem damage? That is the dilemma thoughtful analysts of the climate policy debate have to ponder, since the next few generations’ behaviors will precondition to a considerable extent the long-term evolution of the climate and the planetary ecosystems.

Climate Impacts. Let us consider some of the effects that might occur in the next century if the SRES emissions *do* occur. We can use models to calculate the climatic consequences of those scenarios unfolding, which then allow us to estimate potential impacts of climate changes, and in turn, the benefits of avoiding some of those potential damages through mitigation and/or other measures.

Table 1 shows the IPCC’s summary of a number of such projected impacts. These effects have been consolidated into five major reasons for concern and represented graphically, as shown in Figure 4.

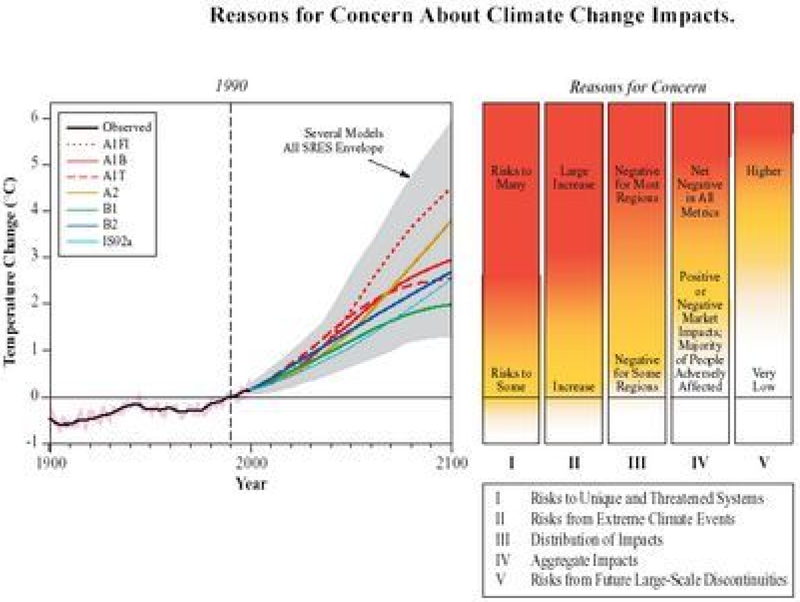
Table 1— Projected effects of global warming during the 21st Century (adapted from IPCC 2001b, table SPM-1)

Projected Effect	Probability estimate	Examples of Projected Impacts with high confidence of occurrence (67 – 95% probability) in at least some areas
Higher maximum temperatures, more hot days and heat waves over nearly all land areas	Very likely (90-99%)	Increased deaths and serious illness in older age groups and urban poor Increased heat stress in livestock and wildlife Shift in tourist destinations Increased risk of damage to a number of crops Increased electric cooling demand and reduced energy supply reliability

Higher minimum temperatures, fewer cold days, frost days and cold waves over nearly all land areas	Very likely (90-99%)	Decreased cold-related human morbidity and mortality Decreased risk of damage to a number of crops, and increased risk to others Extended range and activity of some pest and disease vectors Reduced heating energy demand
More intense precipitation events	Very likely (90-99%) over many areas	Increased flood, landslide, avalanche, and mudslide damage Increased soil erosion Increased flood runoff increasing recharge of some floodplain aquifers Increased pressure on government and private flood insurance systems and disaster relief
Increased summer drying over most mid-latitude continental interiors and associated risk of drought	Likely (67-90%)	Decreased crop yields Increased damage to building foundations caused by ground shrinkage Decreased water resource quantity and quality Increased risk of forest fire
Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities	Likely (67-90%) over some areas	Increased risks to human life, risk of infectious disease epidemics and many other risks Increased coastal erosion and damage to coastal buildings and infrastructure Increased damage to coastal ecosystems such as coral reefs and mangroves
Intensified droughts and floods associated with El Niño events in many different regions	Likely (67-90%)	Decreased agricultural and rangeland productivity in drought- and flood-prone regions Decreased hydro-power potential in drought-prone regions

Increased Asian summer monsoon precipitation variability	Likely (67-90%)	Increase in flood and drought magnitude and damages in temperate and tropical Asia
Increased intensity of mid-latitude storms	Uncertain (current models disagree)	Increased risks to human life and health Increased property and infrastructure losses Increased damage to coastal ecosystems

Figure 4 — Reasons for concern about climate change impacts (source: IPCC Working Group 2 Third Assessment Report, figure SPM-2)



In Figure 4 above, the left part of the figure displays the observed temperature increase up to 1990 and the range of projected increases after 1990, as estimated by IPCC Working Group I (IPCC, 2001a). The right panel displays conceptualizations of five reasons for concern regarding climate change risks evolving through 2100. White indicates neutral or small negative or positive impacts or risks, yellow indicates negative impacts for some systems, and red means negative impacts or risks that are more widespread and/or greater in magnitude. This figure shows that the most potentially dangerous impacts (the red colors on the figure) typically occur after a few degrees Celsius of warming — thus, my use of 3.5 ^{o}C as a tentative "threshold" for serious climate damages in Figure 3 is very conservative. (The European Union has suggested the "dangerous" threshold is about 2 ^{o}C.) The risks of adverse impacts from climate change increase with the magnitude of climate change.

Despite uncertainties surrounding emissions scenarios and climate sensitivity, the IPCC has projected that, if its latest estimate that the Earth's atmosphere will warm somewhere between 1.4 and 5.8 ^{o}C by 2100 is correct, likely effects will include: more frequent heat waves (and less frequent cold spells); more intense storms (hurricanes, tropical cyclones, etc.) and a surge in weather-related damage; increased intensity of floods and droughts; warmer surface temperatures, especially at higher latitudes; more rapid spread of disease; loss of farming productivity and/or movement of farming to other regions, most at higher latitudes; species extinction and loss of biodiversity; and rising sea levels, which could inundate coastal areas and small island nations (see Table 1).

The threat of rising sea levels has been studied in great detail. It is thought that warmer atmospheric temperatures would lead to warming of ocean water (and corresponding volumetric expansion) until the heat was well-distributed throughout the oceans — a mixing time known to be on the order of 1,000 years. Instead of only up to a meter of sea level rise over the next century or two from thermal expansion of warmed ocean waters— and perhaps a meter or two more over the five or so centuries after that — significant global warming would likely trigger nonlinear events like a deglaciation of major ice sheets near the poles. That would cause many additional meters of rising seas for many millennia, and once started, might not be reversible on the time scale of thousands of years.

It is important that scientists continue to develop stronger models and probe the issue of climate sensitivity, as improvements in the science will lead to improvements in our understanding of the potential impacts of various levels of temperature change.

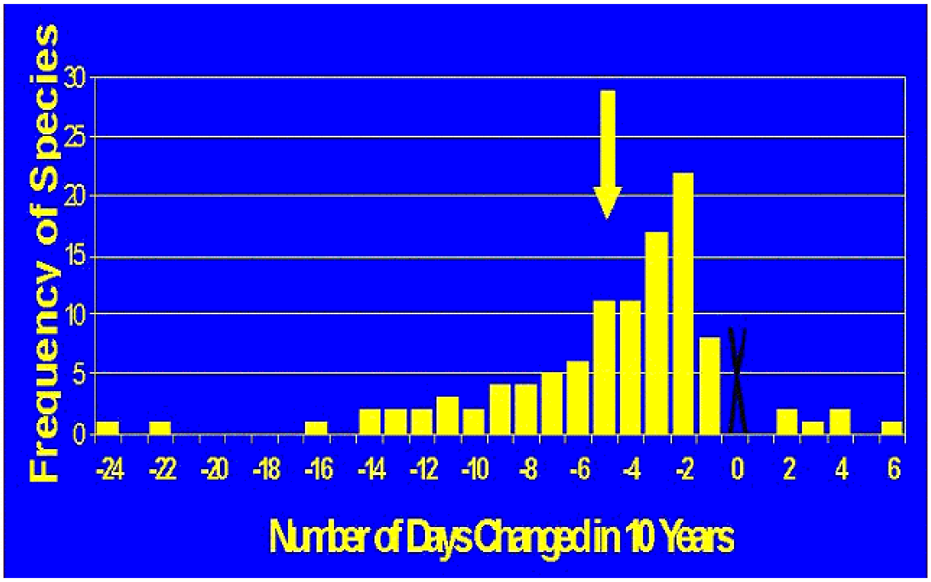
In What Units Can We Measure Climate Damage? Schneider, Kuntz-Duriseti, and Azar (2000) have argued that the best way to estimate the full extent of the climate change-induced damages described above is by examining not just monetarily-quantifiable ("market") damage, but the "five numeraires": monetary loss (market category), loss of life, quality of life (including coercion to migrate, conflict over resources, cultural diversity, loss of cultural heritage sites, etc.), species and/or biodiversity loss, and distribution/equity. Assessing climate impacts in all these categories should ensure a fairer, more accurate assessment of the actual costs of global warming.

The last numeraire, the issue of equity in climate change, is, and will likely continue to be, contentious. Climate change inequality will likely come in two forms. First, it will produce inequity in effects. Some countries or sectors within countries will benefit from a certain degree of warming, whereas others will be harmed by it. The developed countries, who are responsible for most of the greenhouse gases emitted into the atmosphere thus far may not be affected as much as the developing countries for two reasons: first, there is usually higher adaptive capacity in richer, cooler countries than in poorer, warmer ones. Second, developing countries that have not yet experienced the economic fruits of an industrial revolution and want their chance to emit and industrialize fear that policies to restrict emissions will deny them their "fair share" of the atmospheric commons to use—quite literally—as a waste dump. One strategy to solve this problem is "technology leapfrogging," the transfer or development of cleaner technologies to developing countries on a much-accelerated time schedule (relative to the developments that have emerged over a century in now-rich countries).

Moreover, as there are disparities in countries' abilities to pay for global warming-related problems, once again, the developing countries will be affected more yet have less of an ability to pay than the rich nations. While I agree it is essential to deal with climate policy at home—and thus personally applaud this bill before the committee today—we will have to join with other countries to fashion joint solutions in the near future if we are to make progress on the climate change problem.

Nature Is Already Responding. Another numeraire mentioned above was the loss of biodiversity. Very recent studies (e.g., Root et al, 2003; Parmesan and Yohe, 2003) have shown that nature is already responding to climate trends of the past several decades. Figure 5 (below), for example, shows the activities of many plants and animals — such as the flowering of trees and the migrating of birds in the spring — have been occurring earlier due to observed climate trends. That warmer weather would make flowers bloom earlier is hardly surprising, but that "only" 0.6 ^{o}C of warming to date has already caused a statistically significant "discernible impact" on plants and animals is surprising. Moreover, it is sobering to consider what major movements — and extinctions — would likely take place in plant and animal communities if the climate changes by several degrees or more.

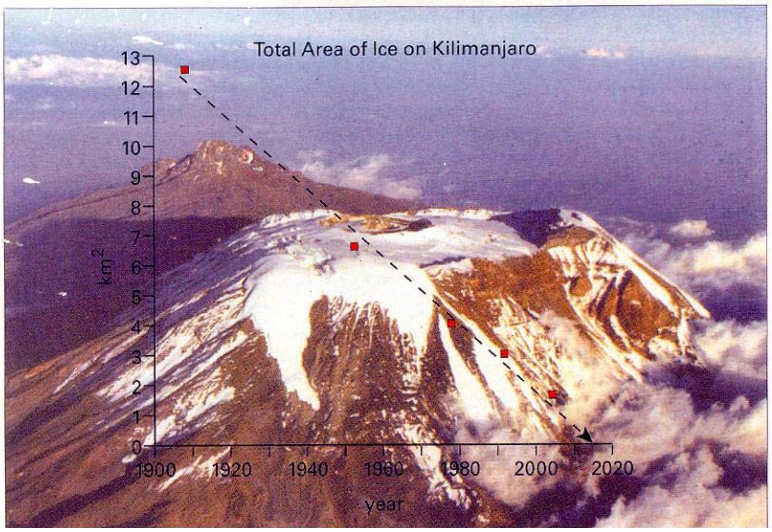
Figure 5. Frequency of species and groups of species with a temperature-related trait changing by number of days in 10 years for data gathered primarily since 1960



The arrow indicates the mean and the "x" indicates no data were tabulated for species showing no clear trait changes. This is a highly statistically significant result demonstrating that there has been a discernible impact of recent climate trends on plants and animals. Their vital activities that are linked to temperature are occurring earlier, in concert with global warming trends. (Source: Root et al, 2003.)

Another clear climate impact is the retreat of mountain glaciers. This problem goes beyond just the disruption of scenic beauty as glaciers in places like Glacier National Park continue to disappear; it can be damaging to societies that are flooded during the glacier-melting stage and will later suffer from lack of water as their current supplies disappear with the glaciers. Figure 6 shows the dramatic disappearance of Mt. Kilimanjaro's glaciers, which have decreased in size by 80-90% relative to 100 years ago.

Figure 6. What will happen to the snows of Kilimanjaro?



The extent of ice cover on Mt. Kilimanjaro decreased by 81% between 1912 and 2000. Disappearing paleoclimate archives such as this are a priority target of the Global Paleoclimate Observing System currently being proposed by the Past Global Changes (PAGES) scientists.

Climate Surprises? The IPCC and others have stated that "dangerous" climate change, including surprises, is more likely to occur with more than a few degrees Celsius of additional warming. Surprises, better defined as "imaginable abrupt events", could include deglaciation and/or the alteration of ocean currents, the most widely-used example of the latter being a slowdown of the Thermohaline Circulation, or THC, system in the North Atlantic Ocean. Ecosystems, especially those already stressed by land use pressures, are particularly vulnerable to rapid climate changes.

Estimating climate damages that are expected to occur gradually and their effects is simple relative to forecasting "surprise" events and their consequences. But rather than being ignored as unlikely, surprises and other irreversibilities like plant and animal extinctions should be treated like other climate change consequences by scientists performing risk assessments, where ***risk*** is defined as ***probability x consequence***. While the possible consequences of climate change have been discussed thoroughly, they are often not accompanied by probabilities. The probability component of the risk equation will entail subjective judgment on the part of scientists, but this is far preferable to overlooking the risk equation entirely.

Policymakers will be better able to determine what is "dangerous" and formulate effective legislation to avoid such dangers if probabilities appear alongside scientists' projected consequences. These probabilities and consequences will vary regionally. In general, temperature rises are projected to be greatest in the subpolar regions, and to affect the polar winter more dramatically than the summer. Hotter, poorer nations (i.e., developing nations near the equator) are expected to suffer more dramatic effects from climate change than their developed neighbors in the North. This is partly due to the lower expected adaptive capacities of future societies in developing nations (when compared with their developed country counterparts), which depend on their resource bases, infrastructures, and technological capabilities. This implies that damages may be asymmetrically felt across the developed/developing country divide. The scenario in which climate change brings longer growing seasons to the rich northern countries and more intense droughts and floods to the poor tropical nations is clearly a situation ripe for increasing international tensions and could cause developing nations to feel increasing resentment towards the most-polluting nations in the twenty-first century. That scenario has clear security implications for the United States.

Regardless of the different levels of vulnerability and adaptive capacity that future societies are expected to have and the need for regional-level assessments that that implies, all people, governments, and countries should realize that "we're in this together." In all regions, people's actions today will have long-term consequences. Even if humanity completely abandons fossil fuel emissions in the 22nd century, elevated CO_2 concentrations are projected to remain for a millennium or more. The surface climate will continue to warm from this greenhouse gas elevation, with a transient response of centuries before an equilibrium warmer climate is established. How large that equilibrium temperature increase is depends on both the final stabilization level of the CO_2 and the climate sensitivity.

Implications for Climate Policy Choices. In the face of such uncertainty, potential danger, and long-term effects of present actions, how should climate change policy be confronted? As discussed previously, climate change, like many other complex socio-technical issues, is riddled with “deep uncertainties” in both probabilities and consequences. They are not resolved today and may not be resolved to a high degree of confidence before we have to make decisions regarding how to deal with their implications. With imperfect, sometimes ambiguous, information on both the full range of climate change consequences and their associated probabilities, decision-makers must decide whether to adopt a "wait and see" policy approach or follow the "precautionary principle" and hedge against potentially dangerous changes in the global climate system. Since policymakers operate on limited budgets, they must determine how much to invest in climate protection versus other worthy improvement projects — like new nature reserves, clean water infrastructure and other health improvement, and better education.

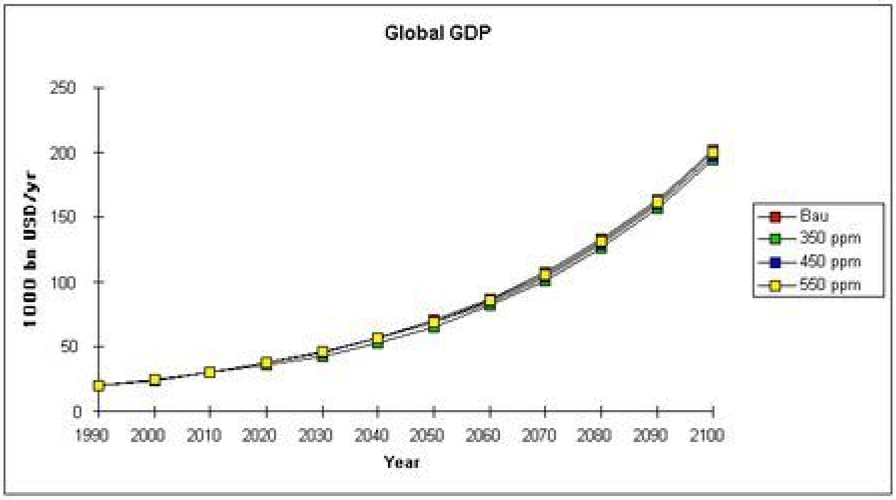
Ultimately, the decision on whether or not to take action on climate change entails a value judgment on the part of the policymaker regarding what constitutes "dangerous" climate change, ideally aided by complete risk assessments provided by scientists. Cost-benefit analyses (CBAs) are also useful in deciding the ifs and whats of climate change policy, but uncertainties and the need for multiple metrics (e.g., the “five numeraires”) make this exercise difficult as well, especially when attempting to estimate the costs of surprise and other catastrophic events.

Any policies that are implemented should encourage, and possibly even go so far as to subsidize, technological change. Encouraging technological change through energy policies, in particular, is of critical importance when addressing climate change. As Figure 3 shows, alternate energy-technology scenarios could dramatically lower the risk of “dangerous” climate change.

Is It Really Too Expensive To Mitigate Global Warming? Christian Azar and I (Azar and Schneider, 2002) developed a simple economy model and estimated the present value (discounted to 1990, expressed in 1990 USD, and assuming a discount rate of five percent per year) of the costs to stabilize atmospheric CO_2 at 350 parts per million (ppm), 450 ppm, and 550 ppm to be 18 trillion USD, 5 trillion USD, and 2 trillion USD, respectively. Obviously, 18 trillion USD is a huge cost; the output of the entire global economy in 1990 amounted to about 20 trillion USD. Seen from this perspective, these estimates of the costs of abatement tend to create the impression that we would, as critics suggest, have to make draconian cuts in our material standards of living in order to reduce emissions and achieve the desired levels of CO_2 concentration. These same critics view the cost estimates as unaffordable and politically impossible.

However, viewed from another perspective, an entirely different analysis emerges. In the absence of emission abatement and without factoring in any damages from climate change, GDP is assumed to grow by a factor of ten or so over the next 100 years, which is a typical convention used in long-run modeling efforts. (The plausibility of these growth expectations is not debated here, but the following analysis will show how GDP is expected to grow with and without climate stabilization policies.) If the 350 ppm target were pursued, the costs associated with it would only amount to a delay of two to three years in achieving this aforementioned tenfold increase in global GDP. Thus, meeting a stringent 350 ppm CO_2 stabilization target would imply that global incomes would be ten times larger than today by April 2102 rather than 2100 (the date the tenfold increase would occur for the no-abatement-policies scenario). This trivial delay in achieving phenomenal GDP growth is replicated even in more pessimistic economic models. These models may be very conservative, given that most do not consider the ancillary environmental benefits of emission abatement (see Figure 7 below).

Figure 7. Global income trajectories under business-as-usual (BAU) and in the case of stabilizing the atmosphere at 350 ppm, 450 ppm, and 550 ppm



Observe that we have assumed rather pessimistic estimates of the cost of atmospheric stabilization (average costs to the economy assumed here are $200/ ton Carbon (tC) for 550 ppm target, $300/tC for 450 ppm, and $400/tC for 350 ppm) and that the environmental benefits in terms of climate change and reduction of local air pollution of meeting various stabilization targets have not been included. (Source: Azar & Schneider, 2002.)

Representing the costs of stringent climate stabilization as a few short years of delay in achieving monumental increases in wealth should have a strong impact on how policymakers, industry leaders, and the general public perceive the climate policy debate. Similar results can be presented for the Kyoto Protocol: the drop in GDP below "baseline" levels that would occur if the Kyoto Protocol were implemented ranges between 0.05% and 1%, depending on the region considered and the model used (see IPCC Working Group III, chapter 8, IPCC 2001c, p. 537-538). The drops in the growth rates for OECD countries over the next ten years would likely fall in the range of 0.005-0.1 percent per year below baseline scenario projections under the Kyoto Protocol. (It should be kept in mind that the uncertainties about baseline GDP growth projections are typically much larger than the presented cost-related deviations.) Returning to the analysis Azar and I did, assuming a growth rate of two percent per year in the absence of carbon abatement policies, implementation of the Kyoto Protocol would imply that the OECD countries would get 20 percent richer (on an annual basis) by June 2010 rather than January 2010, assuming the high-cost abatement estimate.

Similar statements could well be made about the costs associated with this bill that is before the Committee. Although I have not analyzed it myself, I strongly suspect that the loss of GDP from the costs incurred as a result of implementing this measure would be such a small fraction of typically-projected US GDP growth rates that only months of delay in growth would occur, nowhere enough to prevent large increases in personal income from occurring. Thus, this bill is likely to be an inexpensive “insurance premium” to slow down global warming and lower the likelihood of “dangerous” climate impacts.

Whether the costs mentioned are big or small is, of course, a value judgment, but in any case, it is difficult to reconcile the long-term climate benefits of a short-term delay in GDP growth with the strident rhetoric of contrarians like Lindsey (2001) who states in a speech to a colloquim on Science and Technology Policy (organized by the American Association for the Advancement of Science, or AAAS) that “the Kyoto Protocol could damage our collective prosperity and, in so doing, actually put our long-term environmental health at risk” (p.5). Others have made similar statements about this bill, and they have been refuted by careful economic analyses (Pizer and Kopp, 2003; Paltsev et al, 2003). Clearly, such balanced quantitative economic assessments, rather than pessimistic and often politically-motivated exaggerations should guide the evaluations of making bills like this one the laws of the land.

I thank the Committee for asking for my views on this important piece of legislation.

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The Testimony of
Dr. Tom M.L. Wigley

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1. Introduction:

Projections of future climate change made using state-of-the-art climate models suggest that changes over the coming century will be much larger than experienced over the past 100 years. The case for taking action to mitigate these human-induced (or 'anthropogenic') changes rests on the credibility of these models. There is a vast scientific literature on the development and testing of these models, summarized in the recent 'Third Assessment Report' (henceforth 'TAR') produced under the auspices of Working Group 1 of the Intergovernmental Panel on Climate Change (IPCC, Houghton et al., 2001). There are two main methods of model testing – comparing model simulations of the present state of the climate system (such as the geographical patterns of temperature, rain- and snowfall, sea-level pressure, etc.) against observations, and comparing model simulations of past changes in climate with observations.

The most recent climate models are able to simulate present-day climate remarkably well – with errors often less than the uncertainties in observational data sets. Here, however, I will not dwell on this aspect of model validation, but concentrate on the second method – comparison of observed and model-simulated changes. I will show that models simulate temperature changes over the past 100+ years with considerable fidelity provided they are driven (or 'forced') by observed changes in both natural forcing agents (such as variations in the output of the Sun) and anthropogenic factors (such as changes in greenhouse gas concentrations and aerosol particle changes). Natural forcing factors alone cannot explain the past record.

Using the results from this model/observed data comparison, I will give projections of future changes in global-mean temperature for a central scenario for future emissions. These results, which are consistent with projections given in the IPCC TAR, imply, for this particular emissions scenario, a future warming rate of three to five times the warming that occurred over the 20th century. The uncertainty range expands to two to seven times the past warming rate when emissions and other uncertainties are accounted for. Even at the low end, these projections are cause for concern.

2. Temperature changes over the 20th century:

The simplest indicator of climate change is the global-mean, near-surface temperature – the average over the Earth's surface area of temperature observations obtained primarily for the purposes of weather forecasting. After carefully correcting these data for instrumental and exposure changes, global-mean temperature shows a warming trend of about 0.7oC over the past 100 years. This warming trend has, superimposed on it, substantial variability on monthly, annual and decadal timescales associated with natural climate processes such as El Nino and other interactions between the land, ocean and cryosphere (ice) – see Figure 1.

To understand the causes of the century timescale warming trend we make use of climate models. Such models are an efficient way to synthesize and integrate, in an internally-consistent way, the many complexities and interactions of the climate system. The basic procedure begins by defining, independently of the model, the changes in the external drivers of the climate system. We then use these drivers as input forcing factors for the model and run the model to see how well it agrees with observed changes. In doing so, we try to quantify any uncertainties in both the inputs and the model structure to see what affects these uncertainties might have on the model outputs.

The forcing factors are of two types: natural agents like the effects of large volcanic eruptions and changes in the energy output of the Sun; and a variety of anthropogenic factors. Volcanic eruptions have a strong short-term cooling effect (Robock, 1999), and only a minimal effect on decadal or longer timescales. Since the goal here is to understand the century timescale warming, I will not consider volcanic effects further in this analysis, beyond noting that climate models are able to simulate the short-term coolings well. For changes in solar output, I use the recent estimates of Foukal (2002) from 1915 onwards and Hoyt and Schatten (1993) prior to 1915. Other estimates of solar output changes yield similar results. I do not consider the hypothesized amplification of solar forcing through the effects of cosmic rays, partly because there is no credible physical basis for this amplification. I note, however, that any assumed amplification of solar forcing degrades the agreement between model and observed results.

The anthropogenic factors include changes in the concentrations of greenhouse gases (carbon dioxide, methane, nitrous oxide, ozone, and various man-made halocarbons, of which the CFCs – chlorofluorocarbons – are the most well known), and changes in the atmospheric loading of small particles (aerosols) associated primarily with fossil-fuel burning. The greenhouse gases, of which carbon dioxide is the most important, have a warming effect. Aerosols, depending on type, may have either a warming or cooling effect. To date, the cooling effect dominates, but the magnitude of this cooling is still uncertain. In the results below I consider a range of possible values for the magnitude of aerosol cooling. For the climate model I use the model employed by IPCC to produce their global-mean temperature projections (see Wigley and Raper, 2002, and references therein). This is a relatively simple model, but it has been rigorously tested against much more complex coupled Atmosphere/Ocean General Circulation Models (AOGCMs) and is able to simulate the results of these models with high accuracy over a wide range of conditions (Raper et al., 2001).

The simpler model has the advantage that it can be used to examine the effects of uncertainties in the parameters that control the response of the climate system to external forcing. The primary source of uncertainty is the ‘climate sensitivity’ parameter (designated by ‘S’ below). This is usually characterized by the eventual (or ‘equilibrium’) global-mean warming that would occur if we doubled the amount of carbon dioxide in the atmosphere. It has an uncertainty range of 1.5oC to 4.5oC with about 90% confidence. I will give results for sensitivity values of 2oC and 4oC to show the importance of this factor. For more information on sources of modeling uncertainty, see Wigley and Raper (2001).

Figure 1: Observed versus model-simulated changes in global-mean, near-surface temperature. For observed data, see Jones et al. (1999) and Jones and Moberg (2003).

Figure 1 compares observed near-surface temperature changes with model predictions. The four model-based curves consider two forcing cases; one in which the model is driven solely by the primary natural driving force, changes in the output of the Sun (lower two curves), and one where both natural and anthropogenic forcings are used to drive the model (upper two curves). The two curves for each case reflect the main sources of uncertainty in the modeling exercise, the magnitude of aerosol forcing, and the magnitude of the climate sensitivity. The upper two curves show that it is possible to obtain a good match between the model and observations by using a low aerosol forcing (–0.8W/m2 in 1990) combined with low climate sensitivity (S = 2.0oC), or by using a relatively high aerosol forcing (–1.3W/m2 in 1990) combined with low climate sensitivity (S = 4.0oC). Since these values are within their accepted ranges of uncertainty, it is clear that there is no inconsistency between models and observations. The observations, however, do not narrow the ranges of uncertainty for these two parameters, so, in making projections of future change, we need to account for these uncertainties.

The lower two curves show the expected global-mean temperature changes in the absence of anthropogenic forcing. Up to around the mid 1970s both the natural-forcing-only and the natural-plus-anthropogenic forcing cases fit the observations reasonably well. After this, the natural-only case provides an increasingly bad fit, while the natural-plus-anthropogenic case fits the observed warming trend extremely well. It is clear from this that anthropogenic forcing effects must be considered in order to explain the observations.

3. Satellite-based temperature changes since 1979:

One of the more puzzling aspects of recent climate change has been the apparent inconsistency between the linear trends in tropospheric temperatures (from satellite-based Microwave Sounding Units – MSU data), surface air temperatures, and model results (National Academy of Sciences (NAS), 2001). The original MSU data (see Christy et al., 2003, and earlier references cited therein – this data set is referred to below as the UAH data, since its developers are associated with the University of Alabama at Huntsville) showed little or no warming trend since the beginning of the satellite record in 1979, while both the surface data and model results for the surface and for the troposphere (as illustrated in Figure 1) showed a substantial warming trend. The NAS (2001) report concluded that there was no reason to suspect serious errors in any of the trends, but this rather down-played what is really an important inconsistency.

More recent work has moved towards resolving this inconsistency. First, an entirely independent analysis of the raw satellite data (the MSU2 data specifically) has recently been carried by Mears et al. (2003 – these authors are with Remote Sensing Systems, Santa Rosa, CA, so their data set is referred to below as the RSS data). This new analysis has a warming trend that is both larger than the UAH trend and more consistent with both the surface and model data (Santer et al., 2003a). Second, a new reanalysis product (the ERA-40 data produced by the European Centre for Medium-range Weather Forecasting), when used to construct equivalent MSU2 temperature trends, also shows a larger warming trend than the UAH data. (Reanalysis is a technique for synthesizing diverse observational data sets, including both satellite and radiosonde data, to produce an internally-consistent picture of changes in atmospheric meteorological conditions – the ERA exercise is described in Gibson et al., 1997.) Third, analysis of changes in the height of the tropopause – the boundary between the lowest layer of the atmosphere, the troposphere, where temperatures decrease with height, and the layer above this, the stratosphere, where temperatures either change little or increase with height – show that these changes can only be explained if the troposphere is warming (Santer et al., 2003b).

Trends in the three observed data sets, UAH, RSS and ERA-40 are shown in Figure 2, along with model results consistent with those shown in Figure 1. The observed trends have substantial statistical uncertainty because of the ‘noise’ of inter-annual variations about the underlying trend. The statistical uncertainty ranges shown in the Figure are the ‘two-sigma’ ranges, corresponding to 95% confidence intervals. For the model results there are additional uncertainties associated primarily with radiative forcing and climate sensitivity uncertainties, as explained above.

Figure 2: Trends over 1979–2001 and trend uncertainties for different tropospheric data sets.

In a statistical sense, Figure 2 shows that there is no significant difference between any of the trends. While it is clear that the UAH results are qualitatively different from the other results, because of the uncertainties involved it is too soon to pass judgment. As noted by Santer et al. (2003a), model results cannot be used as a basis for selecting one observed data set over another. The key result of this comparison is that it exposes uncertainties that are larger than hitherto suspected. If, however, the UAH data are found to have underestimated the warming trend in the troposphere, then this will resolve an important climatological ‘problem’ and provide a strong endorsement for the validity of current climate models.

4. Supporting evidence for 20th century climate change: a

The temperature results above provide strong evidence for the reality of a strong warming trend over the 20th century. The warming is consistent with model expectations and can only be explained if one includes anthropogenic factors as part of the cause. From Figure

1, the natural warming trend over the 20th century accounts for only 23–32% of the total trend. The observations are also consistent with a climate sensitivity in the standard 1.5oC to 4.5oC range, and are not consistent with a lower value.

These results are consistent with many other lines of evidence that there are unusual changes occurring in the climate system. Not only are global-mean temperature changes consistent with models, but the horizontal and vertical patterns of change also agree with model predictions (TAR). In addition, a sharp cooling trend has been observed in the stratosphere that agrees well with model predictions (Santer et al., 2003a). Sea level has been rising steadily (TAR), partly as a result of warming in the ocean that agrees with model expectations (Barnett et al., 2001) and partly due to the melting of glaciers and small ice sheets (TAR). Sea ice area and thickness have also been decreasing in accord with the changes suggested by models (Vinnikov et al., 1999). Sea-level pressure patterns have shown significant changes and, once again, these changes are similar to those predicted by models (Gillett et al., 2003). The frequency of precipitation extremes has also been increasing (Karl and Knight, 1998; Groisman et al., 1999), a result that agrees both with simple physical reasoning (Trenberth et al., 2003) and with model predictions (Wilby and Wigley, 2002). Finally, based on paleoclimatological evidence, the warmth that characterizes the late 20th century is, at least for the Northern Hemisphere, unprecedented in at least 1000 years (Mann and Jones, 2003).

5. Climate change over the 21st century:

Given the weight of evidence endorsing the credibility of climate models, at least at large spatial scales, we can safely use these models to estimate what changes might occur over the next 100 years. To do this we must first estimate how the emissions of all climatically-active gases will change in the future. As part of the IPCC Third Assessment Report process, a large set of future emissions scenarios was developed, all under the 'no-climate-policy' assumption (referred to as the 'SRES' scenarios for 'Special Report on Emissions Scenarios'; Nakicenovic and Swart, 2000). In total there are 35 complete scenarios spanning a range of assumptions about future population growth, economic growth, technological change, and so on – and each set of assumptions leads to a different set of emissions. In order to predict future climate one must take account of the attendant uncertainties in emissions, since it is these that drive changes in the composition of the atmosphere, which in turn drive changes in the climate system. At each step, in going from emissions to atmospheric composition changes, and from composition changes to climate, there are other uncertainties that must be taken into account. Most of these uncertainties were accounted for in the TAR, where the estimated changes in global-mean temperature over 1990 to 2100 were given as 1.4oC to 5.8oC. A more formal probabilistic analysis was given by Wigley and Raper (2001).

Here, to illustrate the procedure, I will use a single emissions scenario, the A1B scenario, which is roughly in the middle of the range covered by the SRES set. I will then account for uncertainties in aerosol forcing and climate sensitivity as in Figure 1 (recognizing that this does not span the full range of uncertainties in these parameters). The projected future changes in global-mean temperature, compared with past changes, are shown in Figure 3. Figure 3: Projected global-mean warming.

Over 2000 to 2100 the warming range is 2.0oC to 3.6oC, which corresponds to warming rates of roughly three to five times the rate of warming over the 20th century – and temperatures are still increasing at the end of the century. A wider uncertainty range is obtained when other uncertainties are accounted for, as in the TAR analysis (shown by the bar on the right side of the Figure). Even at the low end of the range of possibilities, the warming rate over 2000 to 2100 is double the 20th century warming rate, while at the top end the future rate is seven times the past rate.

Major changes in all aspects of climate will occur in parallel with these unprecedented global-mean temperature increases. Many of these will be beyond our present adaptive capabilities (particularly in lesser developed countries), and will undoubtedly lead to damages to natural ecosystems and managed systems such as agriculture and water resources, and to possibly serious consequences for health and the spread of pests and disease. While the changes and their impacts cannot be predicted in detail, and while some of the consequences of future climate and atmospheric change may be positive, it would be prudent to insure against adverse changes either through improving our adaptive capabilities and/or, through emissions mitigation, reducing the magnitude of future climate change. In the absence of climate policies, as time goes by we will be moving further and further into unknown climate territory and committing ourselves to even larger future changes. Because of the inertia in both socioeconomic systems and the climate system, it is likely that quite aggressive actions may be required to avoid (quoting Article 2 of the Framework Convention on Climate Change) ‘dangerous interference with the climate system’, and ensure that we are able to stabilize the composition of the atmosphere and the climate at acceptable levels.

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The Testimony of
Mr. Paul Gorman
Executive Director, National Religious Partnership for the Environment

Thank you, Mr. Chairman and members of the Committee:

I represent members of the National Religious Partnership for the Environment, an alliance of faith groups across a broad spectrum: the United States Conference of Catholic Bishops, the National Council of Churches of Christ (a federation of 36 mainline Protestant and Orthodox communions), the Coalition on the Environment and Jewish Life (representing 29 national bodies), and the Evangelical Environmental Network (an alliance of evangelical Christian organizations). Each has its own distinctive perspectives. But we share biblical precepts for care of God’s creation, albeit with different, often imaginative forms of expression. For example, supporting renewable and solar energy programs, The Interfaith Power and Light campaign, led by the Episcopal Church, has helped over 300 congregations in California alone conserve energy, preventing 40 million pounds of carbon dioxide from entering the atmosphere. The Catholic Bishops of the Pacific Northwest issued a pastoral letter on protecting the Columbia River. “The Redwood Rabbis” have fought to preserve old growth forests. In addition to asking “What Would Jesus Drive?”, evangelical Christians have worked for extension of the Endangered Species Act. So with bishops in rivers, rabbis in forests, evangelicals in wetlands, and Episcopalians looking to the sun, we’re at least getting out of the house and perhaps making a fresh contribution.

About global climate, change we have fundamental agreements, all of which have been stated in formal declarations at the highest levels of governance, which we would like to submit for the record.

We are convinced of the problem's urgency as documented by eminent scientists world-wide. To amplify a scientific consensus, we affirm a religious and moral consensus.

It seems best, in this brief time --- perhaps as an introduction to those outside the faith community --- to outline four principles of this religious consensus. These are moral precepts that should guide policy.

First, in Genesis, God beholds creation as "very good" (Gen 1:31) and commands us to "till and tend the garden" (Gen 2:15). Humankind is called to stewardship. Second, we read in Psalms, "The Earth is the Lord's and the fulness thereof" (Ps 24:1). Creation's gifts are intended for the well-being of all. Third, we have a paramount obligation to "defend the poor and the orphan; do justice to the afflicted" (Ps 82:3) and to care first for "the least of these" (Math 25:35). Care for God's creation requires justice for God's children and not putting innocent lives at risk. And we call upon the Senate, in your forthcoming deliberations, to address the impact of global climate change on the poor and vulnerable peoples and nations of our planet.

Finally, we have an obligation to the future well-being of all life on Earth, God's "covenant which I make between me and you and every living creature for perpetual generations" (Gen 9:12). Protecting our planet's climate is a religious duty because it embraces everything and everyone on Earth.

Stewardship, covenant, justice, intergenerational equity: these perennial principles have never seemed more meaningful and mandatory. We are all part of God's creation. Environmental isolationism is neither morally acceptable nor faithful to God's Law.

These are high standards, easier to proclaim than to practice. We recognize challenges still before us all: the need for further scientific research; an energy policy which reduces greenhouse gas emissions and steadily moves us beyond reliance on fossil fuels; assurance of economic security and protection of workers. Human habits of materialism and over-consumption lie deeply at the root of environmental degradation. And while we understand the drive of deeply held convictions --- we have some issues here ourselves --- partisanship and short-sightedness seem to be leading to dead ends.

We have to lift our vision. This is an enterprise for the entire human species. So we share these convictions not simply as articles of our own faith but toward a universal moral resolve --- a conversion of hearts and habits ? without which it would seem difficult to meet a challenge of this scale.

We are grateful for your invitation to share these core beliefs. We look forward to discussing them further, and will be communicating them to individual Senators particularly during the October recess. Perhaps you will pass them on as well. But we are here to say this: the religious community is committed to help provide new momentum, as you do here, Mr. Chairman, for what must be a universal enterprise to reduce global warming for the common good.

The Testimony of
Mr. Christopher Walker, Esq.
Managing Director, Greenhouse Gas Risk Solutions, Swiss Re Financial Services Corporation

Introduction

Good morning. My name is Chris Walker and I am the Managing Director of the Greenhouse Gas Risk Solutions team for Swiss Re in North America. Thank you for giving us this opportunity to discuss greenhouse gas emissions (GHG) and its effect on climate change.

Founded in 1863, Swiss Re is North America's leading reinsurer and the world's second largest reinsurer and largest life and health reinsurer. The company is global, operating from 70 offices in 30 countries. Swiss Re has three business groups: Property & Casualty reinsurance, Life & Health reinsurance and Financial Services. We have 2300 employees in the US and 9000 worldwide.

Natural catastrophes have always been of critical concern to the reinsurance industry. Swiss Re has paid claims on every major US catastrophe since the 1906 California earthquake. No other single factor affects the bottom line of our industry or the livelihood of our clients more than natural catastrophes. We believe that climate change has the potential to affect the number and severity of these natural catastrophes and result in very significant impact on our business.

In 1994, Swiss Re published its first publication on climate change, "Global Warming, Element of Risk". At the time, there was still uncertainly as to whether global climate change could be influenced by human intervention. Today, we recognize that global warming is a fact. The climate has changed, visibly, tangibly and measurably. One only has to look at the extreme summer heat in Europe or severe draughts in the Western United States to understand that something has changed.

The question is no longer whether the climate is changing, but how the occurring climate change will affect our existence, what conclusions can be drawn from it and what can be done to mitigate the impact.

Swiss Re supports strategies that serve to protect the global climate system. The need to contain potential consequences of climate change calls for a precautionary global climate protection policy. Swiss Re congratulates Chairman McCain and his entire committee for dedicating a significant portion of your busy agenda to this critical issue.

Assessing the risks

Climate change-driven natural disasters are forecasted to cost the world's financial centers as much as $150 billion per year within the next 10 years, according the UN Environment Program's (UNEP) finance initiative report.

Our analysis indicates that climate change will impact various insurance lines of such as:

- Property and casualty insurance due to potential increases in severity and frequency of storms, floods, droughts, etc., and

- Life and health insurance may experience changes in mortality rates and disease vectors. To enhance our understanding of this potential problem, Swiss Re is funding a study of the health impact of climate change, undertaken by the Harvard Medical School's Center for Health and the Global Environment and the United Nations Development Program.

Offering financial solutions

Swiss Re supports measures to reduce GHG emissions. At present, we see business at a crossroads for how to conduct operations in a carbon-constrained future. Responsible businesses are taking action, but do so blindly without government leadership on this issue.

As a global reinsurer, we work to understand global trends. This may give us an advantage in considering the impact of long-term issues such as climate change and sustainability. Because we operate throughout the world, we are in a unique position to witness what many may not see - the consequences of changing climate on property, life and health in the developing world.

The financial services industry, of which Swiss Re is a leading player, has an opportunity and an obligation to assist in solving this problem through its investment and business expertise. After all, dealing with climate change and commensurate emissions reductions are ultimately financial issues. Reinsurance can play a crucial role in grappling with broad societal issues. As an industry, we can raise awareness and change attitudes. We saw this first hand last year when we participated in the Carbon Disclosure Project with 35 financial institutions representing over $4 trillion in investments. The project wrote to the world's 500 largest companies by market capitalisation asking for the disclosure of investment-relevant information concerning their greenhouse gas emissions. The CDP study found that while 80 percent of respondents acknowledge the importance of climate change as a financial risk, only 35-40 percent were actually taking action to address the risks and opportunities. This is not acceptable risk mitigation. Reinsurers make a living in part by understanding and anticipating risks. As an example, Swiss Re has climatologists and atmospheric physicists on staff and last year published "Opportunities and Risks of Climate Change. Once we understand the risks, we educate our clients and the public in an effort to mitigate these risks. GHG issues are just the latest example of an insurer addressing a risk that grows more prominent with every passing year.

Swiss Re's Greenhouse Gas Risk Solutions

Swiss Re is an industry pioneer in identifying and incorporating risk and capital management to assist clients in dealing with emissions constraints in the most effective and cost efficient manner. We have endeavored to raise awareness of GHG risks and opportunities by hosting well-received and broadly-cosponsored conferences in 2001, 2002 and 2003 at our Center for Global Dialogue in Ruschlikon, Switzerland and in 2002 in New York City. We are considering hosting an event in Washington, DC in 2004.

In 2001,we created Greenhouse Gas Risk Solutions. This unit works to determine where, when and how Swiss Re can play a role in facilitating emissions reductions. For example, my unit focuses on several relevant activities:

• Providing clearing and pooling insurance geared to removing the counter-party and delivery risks that have hampered much of early stage emissions trading potential. • Raising the credit rating of renewable/alternate energy projects through the insuring of construction, technical and operational risks in projects. This insurance has the effect of decreasing the cost of capital for greenhouse-gas-reduction projects.

• Assisting GHG emission reductions with investment asset management. For example, we are developing a project financing mechanism for energy efficiency projects in Eastern Europe.

• In conjunction with the Commonwealth Bank of Australia, we are developing a program for voluntary emissions reductions activities for US and European corporations.

Swiss Re also focuses on risks from GHG emissions reductions to our current customers. For example, we concluded that an exposure potentially exists for Directors and Officers covers (D&O - Professional Liability insurance for senior management). Companies that are not complying with climate-change related regulations could create personal liabilities for directors and officers. Non-compliance with these GHG reduction requirements potentially represents a significant risk. We are educating companies and requiring them to address this issue to prevent losses. These actions are similar to those taken in the mid-1990s before the Y2K crisis was commonly acknowledged. As we know, non-compliance of IT systems would have caused untold losses to companies and shareholders. We consider GHG-related shareholder actions to be a distinct possibility.

Swiss Re has prepared a Directors and Officers questionnaire to be completed during policy renewals for corporate clients. The companies are asked questions concerning emissions, emissions reductions plans and their climate change strategy. The information provided serves as a factor for our risk and underwriting assessment.

Emissions reductions efforts

Worldwide, policy measures to stimulate reductions in GHG emissions are inevitable. From the emerging GHG regulation in the EU, Japan and Canada to the multitude of proposed US federal and state policies, as well as global Non Governmental Organizations initiatives, the public and other stakeholders are exerting increasing pressure for concrete action. Some companies have taken up the challenge and are voluntarily reducing their emissions footprint. But a long and demanding learning curve awaits many companies who have not made GHG reductions a part of their daily business practice. Unfortunately, for US companies operating overseas they face certainty in being regulated for their emissions overseas but potentially a patchwork quilt of non-fungible future legislation and litigation at home.

At Swiss Re we believe that environmental performance is one indicator of overall business performance. Experience has taught us that proactive steps to improve environmental performance leads to better bottom line results. In our view, environment and economics are inseparable, and, as with many things, the secret to success is finding the right balance.

From Swiss Re’s perspective, US regulation of emissions has many benefits including better public health and environmental improvements. We believe the best way to lessen potential loss is through sound public policy utilizing market mechanisms which strike the right balance between environmental precaution and societal policy objectives.

Conclusion

The issue of climate change is real, and we believe a domestic regulatory response is both necessary and inevitable. With this perspective in mind, we believe that we are better off as a company, and industry, if we develop and implement an effective moderate response now. If we wait 5-10 years, we may discover the need for a much more drastic and difficult response

Thank you for the opportunity to testify before this committee. I am happy to answer any questions you may have.