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AN EXAMINATION OF THE IMPACTS OF GLOBAL WARMING ON THE CHESAPEAKE BAY

HEARING

BEFORE THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

SEPTEMBER 26, 2007

Printed for the use of the Committee on Environment and Public Works

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ONE HUNDRED TENTH CONGRESS
FIRST SESSION

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[1]Note: During the 110th Congress, Senator Craig Thomas, of Wyoming, passed away on June 4, 2007. Senator John Barrasso, of Wyoming, joined the committee on July 10, 2007.

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AN EXAMINATION OF THE IMPACTS OF GLOBAL WARMING ON THE CHESAPEAKE BAY

WEDNESDAY, SEPTEMBER 26, 2007

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, DC.

The full committee met, pursuant to notice, at 9:34 a.m. in room 406, Dirksen Senate Office Building, Hon. Barbara Boxer (chairman of the full committee) presiding.

Present: Senators Boxer, Inhofe, Cardin, Warner, Whitehouse.

Also present, Senators Mikulski and Webb.

STATEMENT OF HON. BARBARA BOXER, U.S. SENATOR FROM THE STATE OF CALIFORNIA

Senator BOXER. We call the Committee to order. We welcome our honored guests. I know that Senator Warner has to go down to the Floor and work on the defense bill. He is going to come back as soon as he possibly can, but in deference to his schedule, I would ask if he would like to make his remarks before Senator Inhofe and I do.

Senator WARNER. I thank you, Madam Chairman.

Senator BOXER. Certainly.

Senator WARNER. Then I shall return to this hearing quite promptly.

STATEMENT OF HON. JOHN WARNER, U.S. SENATOR FROM THE COMMONWEALTH OF VIRGINIA

Senator WARNER. I am privileged this morning, together with my colleague Senator Webb, to introduce our distinguished Governor, Governor Kaine, who I have worked with now these several years. It has been my privilege in the 29 years I have been in this institution to work with 10 Virginia Governors. I would say that this one is fast achieving the role of being at the top of his class. He has a heartfelt concern about the issues surrounding global climate changes, the mysteries and what is known in this area. He is proceeding to lead our State to take an important position, along with other States I hope, as we begin to go into the world of the unknowns and try and do what we can at this point in America's history to hopefully join other nations to achieve a measure of global warming recognition and action.

Under your leadership, as you know, Senator Lieberman and I have a bill that will soon come before this Committee. But on this subject, I would like to first mention that it has been my privilege to work on the issues of the Chesapeake Bay for many years. I

harken back to two great Senators, Senator Matthias and Senator Paul Sarbanes and I and others who initiated the earliest legislation with regard to the Chesapeake Bay. We went in there with the best of intentions, and laid a foundation legislatively. I think collectively the several States that border the Bay have begun to pull their fair share of the load and responsibility, together with the Federal Government, but it has to be a joint project.

This magnificent bay is absolutely essential to our ecosystem, and also we must be concerned about a part of the real estate of our great commonwealth, Virginia, which borders the Bay and could be subjected, the Tidewater region, to severe damage if in the future years there is a significant rise in the water levels worldwide. I believe our territory—and the Governor will go into details on this—is one of the lowest of any major city throughout certainly the United States.

So we are anxious to hear from Governor Kaine when his time comes, and thank you, Madam Chairman and the Ranking Member, for allowing me to make a few remarks. I will return as quickly as I can.

[The prepared statement of Senator Warner follows:]

STATEMENT OF HON. JOHN WARNER, U.S. SENATOR FROM THE COMMONWEALTH OF VIRGINIA

Good Morning. I am pleased to welcome today's witnesses, and was pleased to welcome my distinguished colleagues from the Chesapeake Bay region, Senators Webb and Mikulski, Congressman Gilchrest, Governor Kaine, and Governor O'Malley. Your presence here today speaks to the serious nature of the issue today's hearing will examine.

Together over the years, the Congressional delegations from Virginia and Maryland have played a pivotal role in efforts to promote restoration of the Chesapeake Bay. The state governments have enacted strong restoration policies as well. I fear that all this good work, just a drop in the bucket of what it will take to "Save the Bay," is racing an impossible race against increasing global temperatures and sea level rise.

The Chesapeake Bay is a national treasure that sits on the front lines of climate change. The problems that already plague the Bay will be exacerbated if Congress does not fulfill its responsibility and enact a measure to reduce greenhouse gas emissions. It is widely known by now that I have entered into a partnership with my friend and colleague, Senator Lieberman, to craft a climate change bill. We hope to have a bill for introduction in the early weeks of October.

Madam Chairman, I am deeply troubled by the impacts climate change is having in my own back yard. It is an environmental issues as well as an economic issue. The Chesapeake Bay is one of the most significant estuary systems in the United States, but it is greatly changed from the days when blue crabs and oysters were abundant. I fear not only that family traditions will be lost, but that an economic driver for the Eastern Seaboard is in jeopardy.

I look forward to hearing today's witnesses examine not only the impacts climate change is having on the Bay, but possible solutions as well.

Thank you.

Senator BOXER. Thank you, Senator Warner. Thank you very, very much.

This is a very important day for me as Chairman of this Committee, and I know for Senator Cardin who is one of our newest and a wonderful member of this Committee, he and Senator Mikulski, Senator Webb and others have been asking me please to take a look in our own backyard at the impacts that global warming is having already.

This Committee, many members went to Greenland. We saw what is happening there with the ice melt. As a matter of fact, Sen-

ator Mikulski, who sits on a key subcommittee on Appropriations, joined us in that trip. That is why her presence here today is so valuable because we are kind of marrying what we learned in Greenland in looking at the lessons in our own backyard. But they have pressed us to do this hearing. Senator Warner asked us to do it at a time when he could be here. Now, look what has happened with the defense bill, so I am sure he is going to come back. It is a good day for us.

I want to talk about a little bit before our panel some of the impacts that are close to us here in D.C., because you really don't have to travel as far as Greenland to see the impacts of global warming, when you could see them a few miles at the Chesapeake. The Chesapeake Bay is already showing the effects of global warming, including sea level rise, warmer water, erosion of the shoreline, loss of wetlands that protect us from strong storms and provide habitat for our wildlife.

Testimony we will hear from leading scientists today, and a variety of published studies, say that warmer air and water in the region will change the Bay ecosystem, contribute to worsening dead zones, and harmful algae blooms, and encourage the spread of marine diseases and invasive species.

I ask unanimous consent that a report by the National Wildlife Federation being released today, entitled "The Chesapeake Bay and Global Warming: A Paradise Lost for Hunters, Anglers and Outdoor Enthusiasts?"—that is the title of it—be entered into the record.

[The referenced document follows on page 88.]

Senator BOXER. This report concludes that warming will harm fish, oyster, clam and crab populations, as well as the breeding grounds and migration patterns for waterfowl. Fewer birds are expected to make their way to the Chesapeake Bay. This will also disrupt the ability of watermen, hunters and anglers to use and enjoy the Bay.

These kinds of impacts are not limited to the Chesapeake Bay. We are beginning to see some of them in my own home State of California. But there is good news. The good news is that we can do something about this, and we will all be better off for it. The solutions to global warming are good for our economy, good for our security, and good for our planet.

Yesterday, with strong leadership from Senator Sanders, we held a hearing examining green jobs created by global warming initiatives. Witnesses told us that through addressing global warming, we can create potentially millions of new green collar jobs. We heard from very successful businessmen.

We can address global warming, while expanding our economy, improving our energy independence, and enhancing our national security. So those are the reasons why I approach this issue with hope and not fear. I believe we can rise to the challenge. The really great news is this Committee is ready to do that under the leadership of my subcommittee Chair Lieberman and Ranking Member of his Subcommittee Warner. We expect to have a very good bill very soon before this Committee.

So we will rise to the challenge. I am determined that we can and will solve global warming, while strengthening our economy,

creating new green jobs, and saving all of our backyards, including our national treasures, and in that list, certainly the Chesapeake Bay.

So with that, I will turn to my Ranking Member, Senator Inhofe.

STATEMENT OF HON. JAMES M. INHOFE, U.S. SENATOR FROM THE STATE OF OKLAHOMA

Senator INHOFE. Thank you, Madam Chairman.

I appreciate the comments made by Senator Warner. I hope that he does bring out a bill, the Warner-Lieberman bill or whatever they want to call it, because this is the 14th hearing that we have had on global warming. It is time that we go ahead and get some action. So I hope that is the case.

I would like to give the other side of this, that due to an abundance of new peer-reviewed studies, analyses and data error discoveries in the last several months, this year has been a dramatic one for global warming revelations. There has been a scandal at the U.S. Temperature Data Network, where thermometers have been intentionally placed near heat-generating equipment and hot asphalt. Further, the Antarctic ice has grown to record levels since satellite monitoring began in the 1970s. And NASA temperatures data reevaluation have made 1934, not 1998, the hottest year on record.

Now, most interestingly, and the Chairman mentioned the trip to Greenland, Greenland has cooled since the 1940s. According to multiple peer-reviewed studies, current temperatures in Greenland have not even reached the temperatures from the 1930s and 1940s. It is important to note that 80 percent of the manmade CO_2 came after these high temperatures were reached in Greenland. We have seen global average temperatures flatline since 1998, and the Southern Hemisphere—I don't think anyone disagrees—has been cooling in recent years.

Many of my colleagues today will undoubtedly say that the science advocating manmade global warming is settled. In fact, just last month a comprehensive survey of peer-reviewed scientific literature from 2004 to 2007 revealed—and this is very significant—"less than half of all published scientists endorse global warming theory." This is a quote out of the report. The survey used the same search term as was used in the survey that was cited by Al Gore in his movie as proof of consensus, the identical search term that Al Gore used. The study revealed that 528 total papers on climate change, out of those only seven percent gave explicit endorsement of the consensus. The figure rose to 45 percent if one includes implicit endorsement over the acceptance of the consensus without explicit statements.

While only six percent reject the consensus outright, the largest category, 48 percent, is neutral papers refusing to either accept or reject the hypothesis. This led the science publication Daily Tech to conclude in August, just last month in 2007, "this is no consensus." Let me repeat. Just last month, a comprehensive survey of peer-reviewed scientific literature from 2004 to 2007 said less than half of all published scientists endorse global warming theory. This is a huge change from 5 years ago and 10 years ago, but science does improve as time goes by.

With regard to the Bay, its sea levels have been rising for thousands of years. The Bay itself is a product of a rising sea level. The Bay is at best 10,000 years old, and recognizable to us in its current form only in the last 5,000 years. Further, according to the U.S. Geological Survey, the Bay has risen about 6 inches per century over the last 6,000 years. According to the Maryland Department of Natural Resources, the sea level rise is due to naturally occurring regional land subsidence. The land is subsiding at a rate of 1.33 millimeters per year.

In its report on global warming, the Chesapeake Bay Foundation noted that much of the area is actually sinking due to the geological processes that began during the last ice age. The Bay and its sea life have adjusted to its constant rise in sea level and will continue to adjust, and if the pollution issues can be brought under control, it will continue to flourish.

I think this hearing should not have been about the impact of global warming on the Bay, but rather propose that this hearing should have been on the Bay's health, the pollution sources, the local economy, and the water quality. In 2000, Virginia, Maryland, Pennsylvania and the District of Columbia signed the Chesapeake 2000 Agreement, whereby they committed to reducing loadings sufficient to remove the Chesapeake and its tributaries from EPA's list of impaired waters by 2010.

In 1985, 358 million pounds of nitrogen were delivered to the Bay's tidal waters. By 2005, nitrogen loadings into the tidal waters were down to 286 million pounds. However, as noted in last year's Inspector General report, the average rate of decrease in nitrogen loadings is about 3.4 million pounds annually. In order to meet the 2000 Agreement's goal of removing the Bay from EPA's impaired water list, nutrient loadings must be reduced by 16 million pounds annually. According to the 2006 Chesapeake Bay 2006 Health and Restoration Assessment, the signatories have met fewer than 50 percent of their restoration goals. We should examine those goals.

I will submit the rest for the record, because what I am saying, Madam Chairman, is that there are problems with the Bay that need to be addressed, pollution problems, and I think perhaps we could do that, and maybe another hearing would be more appropriate.

[The prepared statement of Senator Inhofe follows:]

STATEMENT OF JAMES M. INHOFE, U.S. SENATOR FROM THE STATE OF OKLAHOMA

Today's hearing is on the impact global warming is having on the Chesapeake Bay. It is also this Committee's 14th hearing on global warming. It was my hope that we would begin having hearings and discussions on actual bill language so that Members can begin to understand the intricate details of how many of the ideas mentioned today would work in reality. Due to an abundance of new peer-reviewed studies, analyses, and data error discoveries in the last several months, this year has been a dramatic one for global warming revelations. There has been a "scandal" of U.S. temperature data network where thermometers have been erroneously placed near heat generating equipment and hot asphalt. Further, Antarctic ice has grown to record levels since satellite monitoring began in the 1970's and NASA temperature data re-evaluations have made 1934—not 1998—the hottest year on record in the United States.

Most interesting, Greenland has cooled since the 1940's. According to multiple peer-reviewed studies, current temperatures in Greenland have not even reached the temperatures from the 1930s and 1940s. It is important to note that 80% of man-made CO_2 came after these high temperatures were reached in Greenland. We

have seen global average temperatures flat line since 1998 and the Southern Hemisphere cool in recent years.

Many of my colleagues today will undoubtedly say the science advocating man-made global warming is settled. In fact, just last month, a comprehensive survey of peer-reviewed scientific literature from 2004–2007 revealed "Less than half of all published scientists endorse global warming theory." The survey used the same search term as that used in a survey cited by Al Gore in his movie as proof of the consensus.

The study revealed that of 528 total papers on climate change, only 7% gave an explicit endorsement of the consensus. The figure rose to 45 percent if one includes implicit endorsement, or the acceptance of the consensus without an explicit statement. While only 6% reject the consensus outright, the largest category (48%) is neutral papers, refusing to either accept or reject the hypothesis. This lead the science publication Daily Tech to conclude in August 2007 "This is no 'consensus.'" Let me repeat, just last month, a comprehensive survey of peer-reviewed scientific literature from 2004–2007 revealed "Less than half of all published scientists endorse global warming theory."

With regard to the Bay, its sea levels have been rising for thousands of years. The Bay itself is the product of rising sea level. The Bay is at best 10,000 years old and recognizable to us in its current form only in the last 5,000 years. Further, according to the U.S. Geological Survey, the Bay has risen about 6 inches per century over the last 6,000 years. According to the Maryland Department of Natural Resources, the sea level rise is due to naturally occurring regional land subsidence. The land is subsiding at a rate of 1.33 millimeters per year. In its report on global warming, the Chesapeake Bay Foundation noted that "much of the area is actually sinking due to geological processes that began during the last ice age." The Bay and its sea life have adjusted to its constant rise in sea level and it will continue to adjust and if the pollution issues can be brought under control, it will continue to flourish.

This hearing should not have been about the impact of global warming on the Bay but rather I would propose that this hearing should have been on the Bay's health, the pollution sources, the local economy and the water quality. In 2000, Virginia, Maryland, Pennsylvania and the District of Columbia signed the Chesapeake 2000 Agreement whereby they committed to reducing loadings sufficient to remove the Chesapeake and its tributaries from EPA's list of impaired waters by 2010.

In 1985, 358 million pounds of nitrogen were delivered to the Bay's tidal waters. By 2005, nitrogen loadings into the tidal waters were down to 286 million pounds. However, as noted in last year's Inspector General report, the average rate of decrease in nitrogen loadings is about 3.4 million pounds annually. In order to meet the 2000 Agreement's goal of removing the Bay from EPA's impaired waters list, nutrient loadings must be reduced by 16 million pounds annually. According to the 2006 Chesapeake Bay 2006 Health and Restoration Assessment, the signatories have met fewer than 50% of their restoration goals. We should examine why those goals have not been met, whether the goals were realistic, whether the resources exist to meet them and where best to devote limited federal dollars in the effort. According to the Congressional Research Service, the federal government spent $58 million in 2006 directly on Chesapeake Bay programs and projects. This does not include any funding received through the two state revolving loan funds or the USDA conservation programs. We should be discussing whether that money was well spent or should be focused elsewhere.

I think today is a lost opportunity. While much of the testimony is focused on global warming, I remain hopeful we will be able to learn about local solutions to the problem of nutrient and sediment loadings.

Senator BOXER. Thank you very much, Senator. I think Senator Cardin will talk about how we are doing that in the WRDA bill that you were so helpful on.

Senator Cardin.

STATEMENT OF HON. BENJAMIN L. CARDIN, U.S. SENATOR FROM THE STATE OF MARYLAND

Senator CARDIN. Well, Madam Chair, thank you very much.

I have the deepest respect for my colleague, Senator Inhofe. The two of us have been working together for many, many years and I respect his views. I must tell you I agree that science does im-

prove as time goes on, and we know a lot more today than we knew a decade ago. We now know a lot more about the dangers of global warming.

I regret that you weren't on our trip to Greenland, because you would have seen first-hand the impact of the warming climate in Greenland, the ice loss which is dramatic and occurring literally as we see from year to year. It is a dramatic indication of the risks that we face as a world because of global warming.

I do want to acknowledge that global warming is a most serious threat to the Chesapeake Bay, but it is not the only threat. The nitrogen levels are a major concern. I want to thank Senator Inhofe, as I did on the floor of the U.S. Senate, and Senator Boxer, for their extraordinary leadership to get the water bill passed, the first reauthorization in 7 years. It has a major emphasis on the Chesapeake Bay and on the issues that Senator Inhofe mentioned on cleaning up the Bay, including dealing with wastewater treatment and the traditional programs that the Federal Government has been a partner with our States and local governments and private sector, in dealing with the pollution problems of the Chesapeake Bay.

There is no one answer to the Chesapeake Bay, but global warming is a serious problem and one that we can deal with. I think that is very much indicated by the distinguished group of witnesses that we have with us today, starting with the senior Senator from Maryland, Senator Mikulski, who has been a tireless fighter on behalf of the Chesapeake Bay, and understands the importance it has not only to the economy of our region, but what makes this region so unique, and the fact that this is a national model on how communities can work together with government to improve the quality of a very difficult, but important, body of water. So Senator Mikulski, I thank you for your leadership on these issues.

It is also nice to have Senator Webb and Congressman Gilchrest with us. Senator Webb and I were elected to the U.S. Senate this year and he has taken on the challenge of the Chesapeake Bay. I thank you very much for your leadership.

Congressman Gilchrest represents the entire Eastern Shore of Maryland and has been an outspoken advocate of sensible ways to improve our environment and maintain a way of life that is so unique to the people of the Eastern Shore. I thank you for your leadership.

I particularly appreciate your Governors being here today—Governor O'Malley and Governor Kaine. Both are leaders on the Chesapeake Bay issues. Governor O'Malley has been Governor just for a few months and he has already shown his dynamic leadership to the people of Maryland. He chairs the Chesapeake Executive Council. It has initiated the Regional Greenhouse Gas Initiative in our State, and we thank you for that. Governor Kaine has taken on the leadership of Virginia as an active partner on our Chesapeake Bay restorations.

I also want to acknowledge the work of Senator Warner. I am glad that Senator Warner mentioned Senator Matthias and Senator Sarbanes. All have been real champions of the Chesapeake Bay. We will hear later from some outstanding experts. Don Boesch is one of the world's leading scientists on coastal systems. Pastor

Rick Edmund, who will tell us first-hand the problems of Smith Island and the erosion there, and the sea level change, the effect that it is having. He is one of our leaders in the faith community. Will Baker is the longtime president of the Chesapeake Bay Foundation, 190,000 members that are committed to restoring the Chesapeake Bay.

Just very quickly, according to Maryland Emergency Management, Maryland is the third most vulnerable State to flooding. All-State Insurance has announced that it will no longer underwrite new homeowners' policies in much of Maryland because of rising sea levels and the increasing rate of severe storms which scientists tell us are associated with global warming. There you see what has happened to our State, the vulnerability to flooding in Maryland.

About one third of Blackwater Wildlife Refuge has been lost in the past 70 years, and Smith Island has lost 30 percent of its land to rising sea levels since 1850. Madam Chair, it is no exaggeration to say that global warming presents a grave long-term risk to the restoration of the Chesapeake Bay.

We salute the strong actions already being undertaken by the States of Maryland and Virginia, but it is time for national leadership on global warming. I look forward to hearing from our distinguished witnesses today, and this Committee taking forceful action on climate change. It is important for the Chesapeake Bay. It is important for our Country. It is important for the globe in which we live. I look forward to hearing from our witnesses.

[The prepared statement of Senator Cardin follows:]

STATEMENT OF HON. BENJAMIN CARDIN, U.S. SENATOR FROM THE STATE OF MARYLAND

The Chesapeake Bay is America's largest estuary and a natural resource of global significance. The United States Congress has called it "a national treasure." But today the Chesapeake Bay faces perhaps a serious challenge.

Global warming presents a present and growing threat to public safety, to key Bay species such as blue crabs and rockfish, and to the fragile lands that surround the Chesapeake.

According to the Maryland Emergency Management Agency (MEMA), Maryland is the third most vulnerable state to flooding.

Allstate insurance has announced that it will not longer underwrite new homeowners policies in much of Maryland because of rising sea levels and the increasing rate of severe storms, which scientists associate with global warming.

In a report being released today, the National Fish and Wildlife Federation warns that we are likely to lose all of the winter flounder and soft-shelled clams in the Bay because water temperatures will simply be too hot for them to survive.

About one-third of Blackwater Wildlife Refuge has been lost in the past 70 years and Smith Island has lost 30% of its land to rising sea levels since 1850.

It is no exaggeration to say that global warming presents a very grave long-term threat to the restoration of the Chesapeake Bay.

We salute the strong actions already being undertaken by our states of Maryland and Virginia. But the time for national leadership on global warming is now. I look forward to hearing from our distinguished witnesses today and to this Committee taking forceful action on climate change in the near future.

As the experience of the Chesapeake Bay makes clear, we can't afford to wait any longer.

Senator BOXER. Thank you very much.

I know that Senator Inhofe is going to a meeting where he is trying to help us get that WRDA bill——

Senator INHOFE. At the White House. That is right.

Senator BOXER [continuing]. Get that WRDA bill signed into law. So Senator, you wanted to make a comment?

Senator INHOFE. I did want to make one comment. There is no one I love more than Senator Mikulski. We are very, very close. We actually have been together on a lot of our Thursday afternoon meetings. But I have to object to have the Senator sit at the dais, because we have never done that in the history of this Committee. I know this came up a couple of times when I was Chairman of the Committee, and I hope you understand that.

Senator MIKULSKI. Madam Chair, may I respond?

Senator BOXER. Yes.

Senator MIKULSKI. Madam Chair, you will hear in my testimony that the subcommittee that I have the proud honor to Chair, Commerce, Justice and Science, funds 85 percent of the science that is done on global warming. I ask to sit at the dais in two capacities. Number one as the Senator from Maryland, because this is a hearing, and I would of course be happy to be joined by my colleague. I am delighted that our colleague from the House, Congressman Gilchrest is here. We do function as Team Maryland on the issues related to the State.

The second reason that I wanted to sit at the dais, though, is that I do fund 85 percent of the science that this Committee relies upon, all that information that Senator Cardin has conveyed up there and that Senator Inhofe conveys comes from our committee. I might add, the committee is the Mikulski–Shelby Committee. We really do function on a keen bipartisan basis.

I will yield to the Senator's objection, but I will ask as a courtesy since 85 percent of what we fund and you rely on, I will assume my seat behind you, as I am behind you 100 percent, and I will function as a staff member to the Committee.

Senator INHOFE. Let me respond. First of all, if the Chairman would agree, this would be a one time only event, since it hasn't happened before. I would have no objection. I would just make the exception for this meeting. Would you agree?

Senator BOXER. Senator, I am not going to agree to that. I am the Chairman of this Committee. I have spoken with you. You knew this was coming. I asked if Senator Mikulski could join us. You said that it is not allowed. I went back to the Parliamentarian. There is absolutely no rule against this, and many committees do this. I can't tell you from the day one whether this Committee has ever done it, and I don't think you can either.

Indeed, it is permissible. It seems to me that we may not agree on this issue. Lord knows, we don't. We agree on others. But we should have a sense of comity here. This is a colleague who would bend over backwards for you if you ever asked her for anything. I am going to ask unanimous consent that we allow Senator Mikulski to join us today.

Senator INHOFE. I object. Let me reserve the right to object.

What you say is partially right, but it is unprecedented in this Committee. There is not a time, and we have done some research to see if that has ever happened before. It hasn't happened before. We tried it when I was Chairman of the Committee. It was objected to. But I am willing to make the exception for you, Senator Mikulski, and I hope that you will be seated up here and will accept the invitation.

Senator MIKULSKI. Madam Chair, if I might, as again a personal privilege. We need to focus on the issue of global warming and the impact on the Bay. We have two outstanding Governors here. I want the focus of the hearing to be on the Chesapeake Bay and global warming, and not on myself.

I yield to the ruling of the Chair.

Senator BOXER. Well, the ruling of the Chair, if I had the chance to rule, would be that you would be joining us. We have had objection, and I just might say, let's just——

Senator INHOFE. I am trying to——

Senator BOXER. I understand you are trying to move on, and I appreciate it, but I think it is important to take a moment here, and I will do that. This is an outrage. This is my friend.

Senator INHOFE. It is an outrage to invite——

Senator BOXER. If I might conclude, please. It is an outrage to object to a sincere colleague who wants to work with us on a bipartisan basis that is so close to her heart. I am offended. It doesn't diminish my wanting to work with you in the future. I mean, Senator Inhofe was going to go to the floor and object to the committee's meeting today if this happened. And he has to leave us and I would not do something behind his back, so that is why we are having——

Senator INHOFE. And that is why I am inviting Senator Mikulski to sit up here on the dais and participate. We will make an exception if you would agree that this is an exception we are making for Senator Mikulski.

Senator CARDIN. Will the Senator yield?

Senator INHOFE. I don't see a problem with that.

Senator CARDIN. Would the Senator yield for a moment?

Senator INHOFE. Yes.

Senator CARDIN. I appreciate your concern that we stick to the rules of the House, but we have a problem in getting Senators to attend hearings. It seems to me that it is helpful if we could have the benefit of another Senator in questioning the really distinguished panel that we have here. I would just urge you—I understand that you have the right to object and I understand your concern. I agree with Senator Mikulski, today's hearing is so important, just so important, the subject that we are dealing with. It is not about one Senator. It is about the issue of the Chesapeake Bay and the relationship of global warming and the relationship to the other issues that you raised. I just think it would be so helpful for this Committee to have the expertise of Senator Mikulski.

Senator INHOFE. And I agree, Senator Cardin. I agree with everything you just said. So why don't you sit up here and we will make that exception for today. I would be delighted to do it.

Senator BOXER. Okay, we will make the exception today, and I am not stating that this will be the only time I will ask for that, but please join us.

Senator INHOFE. Thank you.

Senator MIKULSKI. Thank you very much, Madam Chair.

Senator INHOFE. Thank you, Senator Mikulski.

Senator BOXER. Thank you, Senator.

Senator MIKULSKI. I also thank you, then, for the extension of that courtesy.

Senator BOXER. All right.

Now, I think we are ready to get started now.

Senator MIKULSKI. Who kicks it off?

Senator BOXER. Senator Mikulski, with that tremendous introduction, we welcome you. All of us do.

[Laughter.]

Senator BOXER. We urge you to begin.

STATEMENT OF HON. BARBARA MIKULSKI, U.S. SENATOR FROM THE STATE OF MARYLAND

Senator MIKULSKI. It is more than the ice caps that face a meltdown, Madam Chair.

[Laughter.]

Senator MIKULSKI. First of all, I want to thank you for holding this hearing as one of your hearings on the impact of global warming on our Country and on the world. I want to thank the members of the EPW Committee, and certainly my colleague, Senator Cardin, and a special comment to Senator Warner, who has been a long-time champion. He is a defender of the United States of America, and also of this planet itself. He has done it as a warfighter and he now continues to do it in protecting the Chesapeake Bay and being concerned about these environmental issues.

As you can see, we are here at this table on a bipartisan basis. We are so pleased that you are focusing on the Bay, because too often the thoughts about global warming are about polar bears in Antarctica, and it seems very removed from the everyday life of what American citizens face.

What we are so excited about that you are focusing on is regional impact, the impact of global warming will have a stunning affect on how we live in our own Country, and could even create an international series of security crises.

Madam Chair, you visited our State. You know that the Bay is not only a great estuary, but it is part of the soul and culture and economy of our great State of Maryland and Delaware. What we know is that if anything happens to the Bay, Maryland as we know it will come to an end. You will hear from our distinguished Governor and Governor Kaine. You will hear from people who have worked on the Bay as scientists and watermen that will be able to tell you about it. Because if the Bay goes, so will Maryland and so will Virginia, so will our way of life, so will our economy.

There will be no inner harbor. There will be no agriculture. Good-bye to crabs. Good-bye to oysters, watermen, farmers. So it is the little people with dirt under their fingernails. It is the people who are inventing dot.com ideas in our digital harbor. All of that will be wiped out if the sea levels and temperatures rise.

Now, we believe that whatever decisions that the Committee makes should be made with sound science. As you know, I stand for ungagged, unfettered science to tell us what we need to do. In our outstanding trip to Greenland, as you know, it was the triumph of the geek. They told us what we needed to know scientifically.

Madam Chair, I won't repeat everything I stated earlier, but our committee, Commerce, Justice and Science, Senator Shelby and I fund 85 percent of all of the climate change science, including for NASA, NOAA and the National Science Foundation. Remember,

our own advisor for our Greenland trip told us he could do his work because of the National Science Foundation. You remember our European friend said we were the indispensable Nation on climate change research because of what NASA does.

I won't go into this Committee here about what we do, but we have a coordinated effort in our subcommittee, working on a bipartisan basis with Senator Shelby to continue taking a look at what is happening and what we can do with best practices that are affordable, from satellite research to working with people on the ground.

You will hear from my colleagues about other things that we have done to protect the Bay, from everything from trying to deal with water and sewer runoff, to research on oysters and crabs, and the EPA Bay Program. But all solutions are local, and I want to very much today bring to the table someone who I believe is an outstanding leader on the Chesapeake Bay and the environmental issues.

I want to introduce Governor Martin O'Malley, who has been a great partner in saving the Bay. Governor O'Malley is a true innovator, taking what he did as Mayor of Baltimore with his CitiStat program, in other words, back to data. We want to be data-driven, science-driven, policy-driven that links outcomes with cost. He created something called BayStat, which is going to establish an accountability process to measure and evaluate restoration efforts up and down the Bay.

He created the Maryland Commission on Climate Change, and he is going to tell you about it. He is not only a leader in our State, but in this Country. I am pleased to introduce him and following will be a wonderful panel of people from watermen to scientists to advocates on the Bay.

I thank you for holding this hearing. I thank you for defending the Bay, and I thank you for defending me.

[Laughter.]

[The prepared statement of Senator Mikulski follows:]

STATEMENT OF HON. BARBARA MIKULSKI, U.S. SENATOR FROM THE STATE OF MARYLAND

Thank you Chairwoman Boxer, for holding this hearing today on the impact of global warming on the Chesapeake Bay. Thank you also to the members of the EPW Committee, including Senator Ben Cardin, my great partner in the Senate and a champion for the Bay, and Senator John Warner, who I've worked with for many years on the Bay and other issues important to Maryland and Virginia.

I'm excited to be here today because global warming is not just about polar bears—it's about the future of the planet itself It is an inconvenient truth. We need to look at this problem locally to see the real consequences.

The coastal senators are already seeing and feeling this problem. Our sea levels are rising, our wetlands are disappearing and our islands are underwater. We're looking at the possibility that our agriculture will be wiped out and there won't be a Baltimore Harbor.

In Maryland, the Bay Is our economy, our culture, our soul. Being a waterman is not just a job; it's a way of life. At the same time, we know that Maryland has a turbo economy and we need wise practices to balance the demands on our environment and our economy.

It is my proud job, as the Chairwoman of the Commerce Justice Science (CJS) Appropriations Subcommittee, to fund 85 percent of climate change science. And I am happy to work with you, the authorizers, to make sure we have sound science that is ungagged, unbought and unbossed—to let science speak for itself.

We are here today to discuss how we should fix this problem. I sat down with my Environmental Advisory Board and asked them, 'What is the real impact of

global warming on the Bay? What have we done to fix it? What more can we do?' They gave me valuable information and I greatly appreciate all their help. Based on their feedback, we decided to hold this hearing to open a dialogue between government officials, scientists and local Bay residents so we can discuss problems currently facing the Bay and what our next steps should be.

Through three presidents, I've been fighting to restore the health of the Bay. Every year, I fight for $20 million for the Chesapeake Bay Program, bringing together federal, state and local government, and community groups to create solutions for Bay clean up to restore water quality, habitats and fisheries. I've been helping scientists and researchers find the best ways to restore oysters and crabs in the Bay, fighting for almost $13 million for oyster reseeding since 2001 and more than $20 million to build new oyster reefs since 1995. This is important because oysters help filter pollutants out of the Bay and restoring oysters also helps maintain jobs and opportunities for our waterman. Crabs are also a vital part of the Bay's ecosystem and support jobs in a struggling region of my state, so I've been helping scientists find new methods of breeding and releasing crabs, providing nearly $12 million since 2001.

Our local communities who can't afford to improve water quality also need help. That's why I've been fighting for increased funding for water and sewer infrastructure for Maryland, which received more than $21 million in 2006.

I am Chairwoman of the Commerce Justice and Science (CJS) Appropriations Subcommittee. My CJS bill informs policymakers' decisions on what to do about global warming. In fact, 85 percent of climate change science is funded in CJS with almost $1.6 billion per year. Without the science that is funded in the CJS bill, policymakers on the Environment and Public Works Committee would not have the important benefit of this sound science to base regulatory and policy decisions.

The CJS bill funds NASA's [National Aeronautics and Space Administration] earth science programs at $1.1 billion. This supports the important research missions that study chemicals and aerosols in the atmosphere, the earth's energy budget and links between oceans and climate. NOAA's [National Oceanic and Atmospheric Administration] weather and satellite programs, which provide short and long term observations and predictions of our weather and climate, are funded at $300 million per year. NSF's [National Science Foundation] research is funded at $200 million per year, and supports competitive, peer-reviewed, basic 'ground truth' research by university scientists.

I stand ready to work with the authorizers and I am happy you're having this hearing today. There may be international agreements and national bills, but this is ultimately a local issue. That is why its so important to hear from the state and local officials. I am proud to introduce Governor Martin O'Malley, who has been a great partner with me in saving the Bay. Governor O'Malley is a true innovator, taking what he did when he was mayor of Baltimore—City Stat, a program he pioneered to make government more efficient—and creating Bay Stat, which establishes a process of accountability for measuring and evaluating efforts to restore the Bay. He also created the Maryland Commission on Climate Change, which will perform an assessment of climate change impacts, calculate Maryland's carbon footprint and develop a strategy to reduce greenhouse gases. Governor O'Malley is a leader not just in our state of Maryland, but in this country. He will tell the Committee about his efforts to save the Bay and how we can all work together.

I thank the Chairwoman for this opportunity to open this hearing and introduce Governor O'Malley. I look forward to hearing all of the testimony from the distinguished panelists and coming up with real solutions to these problems. We need to make an action plan on how to make the Bay healthier and how state and federal officials can work together with our partners in the community. The Chesapeake Bay is a national treasure and Maryland's greatest natural resource, but the Bay is in trouble and we need to do everything we can to save it. I will always fight to protect the Bay and the jobs and livelihoods that depend on it. Thank you again for this opportunity, now I turn the microphone over to the Governor of Maryland.

Senator BOXER. Senator, would you do us the honor of joining us, and please take your seat next to Senator Cardin. I would really appreciate it.

Senator Webb, we welcome you. We are so happy. This new class, between all of you, including this wonderful new member sitting right here, you have just added immeasurably to the Senate and we welcome you to this issue and this battle.

STATEMENT OF HON. JAMES WEBB, U.S. SENATOR FROM THE COMMONWEALTH OF VIRGINIA

Senator WEBB. Thank you very much, Chairman Boxer, and Senator Cardin. Let me join in also defending Senator Mikulski here. I think what Senator Cardin said is absolutely true to the process. There are times when we have four committee hearings scheduled at the same time up here. When you have a sitting Senator with the seniority and the knowledge and the tenacity of Senator Mikulski wanting to come up and participate on an issue, we all should be happy about that.

My purpose in coming today really is to give a brief introduction to my good friend, Governor Kaine. Before I do that, though, I would like to thank you for holding this hearing and for all of your leadership on these issues. The Chesapeake Bay is a cherished resource not only for the residents of Virginia and Maryland, but for the Nation as a whole. It is a national treasure, and your recognition of that fact is sincerely appreciated.

Members of the Bay Congressional delegation have a history of working together and with committees of jurisdiction on efforts to protect the Bay. As such, I would also like to take this opportunity to thank you for your Committee's work on the recently passed water resources bill, which contains several provisions for improving the Bay.

As I said, my real purpose is to introduce our 70th Governor of Virginia and my good friend, Tim Kaine. Years ago when I was a plebe at the Naval Academy, they made us memorize a page about how people were supposed to live their lives. I was thinking about Tim Kaine and this phrase this morning when I was figuring out what I would come to say about him.

Just two brief passages from that long page. Tim Kaine is someone whose conduct proceeds from goodwill and an acute sense of propriety, and whose self control is equal to all emergencies. He is someone who speaks with frankness, but also with sincerity and sympathy, whose deed follows his word, which is what you come to learn in government is so vital to the workings of government; who thinks of the rights and feelings of others; an individual with whom honor is sacred and virtue safe.

He also has provided leadership, following on the leadership of his predecessor, Governor Mark Warner, that has caused the Commonwealth to invest hundreds of millions of dollar in improving the water quality of the Chesapeake Bay. These are significant levels of investment, not only by the State, but also by local governments and communities in the Bay watershed.

Climate change is also an important topic, and the Commonwealth and your Committee have been taking steps to address it. This spring, Governor Kaine issued an executive order that requires State agencies to reduce the amount of energy they consume, to use green building practices, and also encourages procurement of more fuel-efficient vehicles for the State fleet.

Most recently, Governor Kaine released a comprehensive energy plan for Virginia. The plan is widely praised for its broad approach to address energy production and consumption, and calls for dramatic improvements in increasing energy efficiency and conserva-

tion. It also calls for reductions to greenhouse gases to 2000 levels by the year 2025.

Finally, Governor Kaine has made a serious commitment to protecting the natural resources of the Commonwealth for future generations. He has staked out an ambitious goal of preserving 400,000 acres of land during his time in office. Only a year and a half later, he has much to be proud of. Through his leadership and tenacity, when he is not fishing or taking out his canoe, Governor Kaine is known to pitch land conservation easements to unsuspecting landowners. Virginia has already preserved 164,000 acres. This figure is nearly double the previous year's total.

The benefits of his efforts to conserve land will not only benefit the Chesapeake Bay, but will also improve air and water quality. These goals will, in turn, have a positive affect on the public health and preserve the Virginia countryside for sportsmen, anglers, farmers and tourists alike in the years to come.

I thank the Committee for their attention on this topic, and I thank you for inviting our Governor to speak to you about Virginia's successes.

Senator BOXER. Senator Webb, thank you.

Congressman Gilchrest, welcome to our Committee. Sorry we had to do a little bit of unusual argument.

STATEMENT OF HON. WAYNE T. GILCHREST, U.S. REPRESENTATIVE FROM THE STATE OF MARYLAND

Mr. GILCHREST. We don't have those arguments on the House side.

Senator BOXER. I know. I am sure you are just in shock.

[Laughter.]

Mr. GILCHREST. I was stunned.

[Laughter.]

Senator CARDIN. I do long for the Rules Committee sometimes, now that we are in the majority. It would make life a little bit easier.

Mr. GILCHREST. Thank you, Ben.

I do want to say that we in Maryland, especially on the Eastern Shore, which is sometimes referred to as the 51st State or DelMarVa, but we often refer to the gentlelady from Baltimore as "Schwarzkopf in earrings," which we say very affectionately.

[Laughter.]

Mr. GILCHREST. We all were witnesses here today to show the good faith and the tenacity and the intellect of Senator Mikulski. I am proud to have served with you for so many years and will continue to do so.

Senator Webb and I share some common history in Vietnam, as old Marines. I bring that up for two reasons. One, we just exchanged some war stories briefly before we testified. But the other thing we basically concluded was that we were in Vietnam very often fighting by ourselves with just a few other Marines in a very hostile environment for days or sometimes weeks at a time. We had to be competent. We had to figure things out.

So we got into that frame of reference of understanding that if we were to have integrity with our fellow soldiers, we needed to

know how to do things, do them right, gain the information that was important at the time, and be competent.

So that, as Senator Webb has said what he learned in the Naval Academy, and what I learned lo those many years ago, was that when you look at an issue, you look at that issue through the eyes of someone who is basing their judgment on the philosophy of integrity.

So what I would like to do today is to give you some of my views on global warming and the Chesapeake Bay, not through the political process, not through some distorted ideological point of view, but from an objective analysis of someone who has seen these things happen. I want to make this place a heck of a lot better than we have received it, so that our children and grandchildren and the posterity of America will be proud of this generation.

I also want to thank Governor O'Malley and Governor Kaine for coming here today to say a few words. We know that the environment in the Chesapeake Bay is in trouble for a myriad of reasons, whether it is over-development, chemical contaminants, reduced groundwater capacity for a lot of different reasons, a depletion of the fisheries, especially menhaden and oysters, the significant most important aspect of restoring the Chesapeake Bay because of their filtering of the water. Menhaden are vegetarians. They don't eat other fish. They eat the algae that causes depletion of oxygen.

But let's take a look at global warming and the Chesapeake Bay. Before 1900, we know that there has been subsidence, but we also know that there has been sea level rise, certainly for the last 10,000 years. The sea level rose in Chesapeake Bay three feet every 1,000 years. In the last 100 years, it has risen a foot and a half. Something is going on. We used to have 500 more islands in the Chesapeake Bay.

Most of them are gone. You won't see them on any maps or charts. Poplar Island, for example, used to be 1,500 acres. It got down to less than 5 acres until we started this restoration process. Holland Island had 350 residents, 5 miles long, a mile and a half wide. Now, it is down to 100 acres. Where did Holland Island go? Barron Island was 582 acres. Today, it is 120 acres. There are countless numbers of natural observations that anybody can take that you know sea level is rising. Blackwater Refuge loses 120 acres of grassland a year. That is due to increasing sea level rise.

What will a warmer temperature do? Warmer temperatures deplete the oxygen, stress marine life, fewer bay grasses, more acidic water, and significant ecological change. That is what warmer temperatures will do.

How about stream flow? It will be much more variable. We will have longer dry periods, increased storm intensity, and increased discharge of nutrients and sediments. That is what global warming is doing.

What is its impact on people? Less water during dry spells and on the Eastern Shore, for example, in most coastal areas in Maryland, there is no fresh water. It is all groundwater. Less recharge to groundwater, as a result of these variable dry periods. Coastal homeowners are way more vulnerable to storm and coastal flooding. The aquifer system that much of our population depends on

may not be able to meet future demand. Declining groundwater levels are already evident and problems around the Country.

Now, our district, the State of Maryland especially, has done significant work to try to ameliorate or resolve these issues through green buildings, through better smart growth for our homes, for understanding the nature of sea level rise, understanding the nature of groundwater problems, understanding the nature of a whole host of human activity that is not compatible with nature's design. So we are moving in that direction.

What needs to happen, though, Maryland can't do it alone. I will conclude with this. As a national policy, and we hope that the House and the Senate can work together in this national policy, like Senator Warner said earlier, to reduce greenhouse gases by 80 percent below present levels, or maybe even more, by the year 2050; by a national policy, perhaps cap and trade, dealing with a reduction of greenhouse gases.

Madam Chairman and other members, especially my good friend Ben and Ms. Mikulski, thank you so much for the opportunity to testify this morning.

[The prepared statement of Mr. Gilchrest follows:]

STATEMENT OF HON. WAYNE T. GILCHREST, U.S. REPRESENTATIVE FROM THE STATE OF MARYLAND

Thank you, Madam Chair, Ranking Member Inhofe, and distinguished Committee Members for this opportunity to testify before the U.S. Senate Committee on Environment and Public Works on the nexus of two policy issues that are of paramount importance to me and to my district—Maryland's 1st Congressional District. We hold the Chesapeake Bay and our rural and coastal communities in great esteem. For more than 20 years, local policy leaders and citizen groups have worked against great odds to restore the Chesapeake Bay in a national model of scientific achievement, collaborative effort, and passion. We are now grappling with new challenges, including greater projected growth, the management of biefuel production and its impacts on water quality, and climate change. Affecting every driver of the Bay's overall health, climate change is an additional challenge to an already stressed ecosystem.

Consisting of the entire Delmarva Peninsula within Maryland and portions of western counties that surround the Chesapeake Bay, Maryland's 1st Congressional District relies heavily on the health of the Bay as its economic engine—for abundant seafood, recreation, transportation of commercial goods, tourism, and a growing real estate market. Much of my district is geographically divided from the rest of the nation by the Bay, so the Bay and coastal waters are of even greater importance to the people living and working in the beautiful, bountiful area known as Maryland's Eastern Shore.

My district includes the largest share of Chesapeake Bay shoreline in the Chesapeake Bay watershed, and my constituents will directly experience the impacts of climate change, including coastal flooding, shoreline erosion, and infrastructure damage from severe coastal storms. The Delmarva Peninsula, upon which much of my district rests, is basically a sand bar formed by the confluence of the Susquehanna River delta and the Atlantic Ocean. As a geological feature of water flow, and with its greatest elevation at 100 feet above sea level, the Peninsula is extremely vulnerable to severe weather, flooding, and sea level rise.

As vulnerable as it is to climate change impacts, the Chesapeake Bay and its 64,000 square mile watershed are in a uniquely powerful position, geographically, functionally, and culturally to contribute to reducing and sequestering greenhouse gas emissions. With the highest land to water ratio of any estuary in the world, the watershed and its commitment to restoring the Bay through best management practices, can greatly contribute to the national and even global effort to reduce greenhouse gases. For instance, when we are stuck in traffic in the Washington Metropolitan Area, we are spending just a little bit less time on that than our friends in the New York Metropolitan Area, because of patterns of land use and development. The Urban Land Institute reported recently on the contribution of sprawl to greenhouse gas emissions from vehicles. Better informed and coordinated land use

Planning, new state commitments to control vehicle emissions, and green buildings can solve this problem. We can plan ahead—the Institute predicts that two-thirds of the residences and office buildings needed by 2050 have yet to be built.

The Chesapeake Bay's restoration goals, like planting forest buffers and preserving open space, could help sequester carbon. State and local government and citizen action to increase energy efficiency in buildings and transportation are also helping the cause Counties in my district, like Worcester County along the Atlantic Coast, are not only striving to become energy independent but are also actually planning new communities so that fewer residents and less infrastructure are vulnerable to flooding. As these local actions are taken to both restore the Chesapeake Bay and address and adapt communities to climate change, the core of the climate change problem is the need for a national policy to significantly reduce greenhouse gas emissions.

I come before the Committee today, not only as Maryland's 1st Congressional District Representative, but also the co-chair and co-founder of the Congressional Climate Change Caucus, to urge you to work closely with your colleagues in the House to craft and pass legislation dining this Congress that will meaningfully reduce greenhouse gas emissions to 60 percent to 80 percent below current levels by 2050. The survival of communities in our watershed and the Chesapeake Bay ecosystem depends on it.

This legislation should have broad-based support from environmental and business stakeholders alike. It should not only reduce greenhouse gases, but also help the U.S. economy to grow and to keep the U.S. at the lead of international development of new energy technologies. I cannot stress enough that the policy we ultimately create and pass must be acceptable to utility ratepayers and consumers—it must not significantly reduce their quality of life.

Therefore I urge the Committee, in crafting its legislation, to focus on the first ten to twenty years of the policy's implementation. We must get it right in this time frame because this is when consumers will judge their tolerance for it. It is also during this time that we must invest the capitol and take the necessary risks to develop new energy technology and delivery systems in order to achieve our climate change goals. If the investment we make during this time is not sufficient nor targeted enough, new technology may be insufficient to achieve the downward trajectory of emissions we need over the next 40 years.

I believe a 'tipping point' will occur in this policy debate, after which both the impacts of global warming will be irreversible, even over generations, and our economic opportunity to address the problem will be unrecoverable. I believe this tipping point may occur sooner rather than later. However, the opportunity for climate change policy to generate a stronger U.S. energy economy and a better global environment during those years is tremendous.

Madam Chair, I want to congratulate you and express my profound appreciation for your leadership on climate change. Your persistent work on this issue has helped bring Congress to its own 'tipping point'—the point past which Members can coalesce around a solid piece of legislation that will reduce greenhouse gas emissions and grow the U.S. economy.

The people dedicated to the Chesapeake Bay are enthusiastic, well-informed, and eager to restore the functioning ecosystem of the Bay, including humans as a productive part of the landscape. They have kept the Bay's status in equilibrium, in spite of the millions of people who have moved to this lovely place since the early 1980s. I admire their fierce determination and hope you will join me in supporting Chesapeake Bay restoration—as far as we can take it—2010 and beyond.

Thank you again, Madam Chair, and I look forward to continuing our work together.

Senator BOXER. Congressman, I just want to thank you so very much. It is music to my ears to hear your testimony, and all of the witnesses.

Now it is with great honor I ask Senator Mikulski to please join us next to Senator Cardin.

I ask the next panel, two most distinguished Governors, Hon. Tim Kaine, Hon. Martin O'Malley, respectively Governors of Virginia and Maryland, to join us. We are very, very pleased that you have done so.

Are we going to change the—he needs to get by, please. Thank you. One moment.

Governors, you can decide who would like to go first, because whatever you decide is fine.

STATEMENT OF HON. TIMOTHY M. KAINE, GOVERNOR OF THE COMMONWEALTH OF VIRGINIA

Governor KAINE. Thank you, Madam Chair, and to members of the Committee, it is a real treat to be with you today on an important topic.

I especially am happy to be here with my senior Senator, Senator Warner. I also appreciate being here with Governor O'Malley because Maryland and the other States—Pennsylvania, the District—have shown great leadership and we are happy to talk about this critical issue.

I have been Governor for 20 months. In the 20 months that I have been Governor, we have been able to find $700 million to invest in Chesapeake Bay cleanup, primarily through helping municipalities upgrade sewage treatment. This is by a factor of 10 more than we have done in any previous period of years, but we don't want to see that work that we are starting to do in earnest be jeopardized by what we are seeing in the area of climate change. That is why I am so happy to be here.

The testimony that I filed, the written testimony, summarizes the effects of climate change that we would see in Virginia to the Chesapeake Bay that would cause us grave, grave concern. First, as has been commented upon already, there are a number of dead zones in the Bay that grow. Those dead zones grow with pollution and runoff into the Bay. The work that we are doing in all States to improve sewage treatment practices will help, but as weather events cause more severe storms, that will create additional polluted runoff into the Bay and the chances are significant that that runoff caused by climate change will dramatically increase the prevalence of dead zones.

As sea levels rise, and there has already been good science about the rising sea levels and predictions that there would be some significant additional rise by 2030. You also see salt water intruding further inland. That salt water intruding further inland in Virginia has a dramatic potential effect upon species, both plant and animal species, as the ecosystem changes with salt water intrusion.

We have a significant problem in Virginia and Maryland along the Bay with shoreline erosion over the years, caused by rising sea levels, development, et cetera. Climate change in pushing sea levels further will hasten that erosion and sediment is one of the pollutants that can cause significant problems in the Chesapeake Bay.

We are seeing a loss of wetlands. I am interested in the testimony from the folks from Smith Island today. Tangier Island in the Bay has seen significant loss of wetlands as a result of rising sea levels. Because of the way the Bay has often been fortified to protect from storms, once these wetlands go, there is really no way easy to replicate them. And so wetlands and their effect on storm control, their effect on biodiversity are critical to the health of the Bay. Rising sea levels jeopardize them.

Agriculture and forestry is the number one industry in Virginia. It is the largest industry. Obviously, climate change that affects temperatures, that affects rainfall has a dramatic effect on these

industries, which are very prevalent in the Chesapeake Bay watershed. We see temperature change having a dramatic effect on corn yields, on the cost and challenge of raising livestock. Temperature change effects pests and diseases in forests that can jeopardize forests and it can also spread to agriculture. So these climate change effects, particularly on temperatures, pose a threat to the number one industry in Virginia, ag and forestry.

Finally, the effect on people. The Hampton Roads area of Virginia is our second most populated region. It is 1.7 million people. It is thought to be in the analysis that has been done, the second most vulnerable population, urban population, to the effects of sea rises, next to New Orleans. It is not just 1.7 million people. Hampton Roads is also the center of naval power for our Nation. Military installations in all branches in Hampton Roads are jeopardized in the area.

The storm vulnerability of that region is already something that is critical. Making decisions about evacuating populations in the event of storms is already a very, very difficult thing. As climate change affects storm frequency and the magnitude of storms, that becomes a significant additional problem.

In addition, in the Hampton Roads area we have significant uses of groundwater and the salt water intrusion effect that I mentioned earlier threatens the groundwater relied upon by a huge percentage of Virginia's population.

So the effects of climate change are huge—agriculture and forestry, industry, tourism, biodiversity, effects upon people. And the Chesapeake Bay is a treasure that all Virginians cherish, and we don't want to see the Bay harmed either by pollution that we can control or manmade climate change that we can affect.

Virginia is taking action on climate change. I issued Executive Order 48 shortly into my time as Governor to dramatically push State agencies to reduce energy usage and take steps so that we can begin to address some of the causes of climate change and greenhouse gas emissions. Virginia has joined along with other States the Climate Registry, so that we all can establish standard protocols for measuring the effects of different industry sectors on climate change. Measurement and data has to be the beginning point for deciding what are the right practices for curbing those effects.

Finally, recently we enacted a statewide energy plan for all sectors—consumer, commercial and governmental—to reduce per capita consumption of energy, to reduce greenhouse gas emissions, and to establish a Commission on Climate Change.

I feel good about what we have done in Virginia, but I have to say I think what we do is a poor substitute for what the Federal Government should do, because climate change knows no boundaries, certainly not State boundaries and not national boundaries either. Well-meaning Governors and legislators are tackling this all over the Country, and yet we will do our very best in our own jurisdictions, but necessarily if it is a State by State effort, there will be gaps. There will be overlaps. There will be redundancies. And there will not be the kind of comprehensive approach that this subject needs.

I am extremely pleased with the effort that this Committee is making, and Senator Warner with your comment about the bill you are working on with Senator Lieberman to bring forward a comprehensive and aggressive national policy on climate change.

If I could close just with a quick story. In Virginia right now, we are in the midst of Jamestown mania. It is the 400th anniversary of the founding of English-speaking civilization in this hemisphere on Jamestown Island in May 1607. For years, the original fort at Jamestown Island was thought to be lost. It was thought to be lost because it had washed into the James River right next to Jamestown Island.

An enterprising archaeologist in the early 1990s named Bill Kelso examined the island, and he thought that the conventional wisdom was wrong, and that the fort was still there, and began an excavation that has produced evidence that he was correct. The original Jamestown Island fort and palisades and graves and evidence of our earliest settlers of democracy and founders of this Nation is now available, and is now available for all to see. We have shown it off to the world, and it is 30 yards from the James River today.

It would be amazing, after having thought it lost for centuries, to have found it and reclaimed it, only to have it jeopardized by climate change that we have the capacity to affect. And so I encourage the great efforts of this Committee and look forward to being an ally for you as you go forward toward addressing reasonable and aggressive national policy.

Thank you.

[The prepared statement of Governor Kaine follows:]

STATEMENT OF HON. TIMOTHY M. KAINE, GOVERNOR FROM THE COMMONWEALTH OF VIRGINIA

Chairman Boxer and members of the Committee, thank you for inviting me to be here today. The Chesapeake Bay is one of our Commonwealth's most important natural assets, and it has contributed immeasurably to our cultural heritage.

As you know, the Bay is already a stressed system, and the federal government, the Commonwealth of Virginia, the District of Columbia, the State of Maryland and the Commonwealth of Pennsylvania have all made significant investments in restoring the Chesapeake Bay.

In my first year in office, I signed into law a $200 million cash investment in sewage treatment plant upgrades in the Chesapeake Bay watershed. In my second year in office, I signed into law provisions for $250 million worth of bonds to support sewage treatment plant improvements. And just a couple of months ago, an additional round of bonds was issued totaling more than $240 million to assist Virginia localities in the Bay watershed who seek to install advanced technologies to their sewage treatment plants. I believe this nearly $700 million total investment in less than two years speaks volumes—Virginia is very serious about improving the health of Chesapeake Bay.

I am very much concerned that climate change could jeopardize the progress we're making in restoring the Bay. For example, scientists agree that additional temperature changes in the atmosphere and oceans will increase the frequency of extreme weather events that will exacerbate polluted run-off into the Chesapeake Bay, causing the dead-zones in the Bay to grow. This additional pollution, combined with warmer surface water temperatures, will increase environmental stress and disease for key species, such as oysters and striped bass, as well as the loss of important aquatic plants, such as eelgrass. We should also be concerned about effects on the Bay's commercial and recreational fisheries, threatened and endangered species, and breeding ground and migration for waterfowl.

If climate change goes unchecked, the damage will not be limited to the Chesapeake Bay itself. As sea level rises, salt water will intrude further upstream into

current freshwater systems—altering the distributional ranges of key animal and plant species throughout the entire watershed.

Sea level rise and storms will also affect the Bay's physical characteristics, likely resulting in increased shoreline erosion. The Bay and rivers already suffer from the effects of sediment pollution—increased shoreline erosion will only make it worse. Rising sea levels would inundate coastal marshes and other important fish and waterfowl habitats and make coastal property more vulnerable to storms. In fact, some estimates show that up to 80% of Virginia's tidal wetlands could be lost by the end of the century. And because many of our shorelines are armored for erosion control, tidal wetlands will have no place to migrate landward in the face of sea level rise. Our wetlands will become fragmented, lose species diversity, and will no longer be able to serve their ecological function.

Climate change will also affect the Bay watershed's forests, where prospects for insect and pest outbreaks will increased, which also pose a threat to agriculture. As temperatures go up, there will also be reductions in crop yields. For example, corn yields begin to suffer as temperature exceeds 90 °F, and corn crop damage can be severe at 100 °F. Increased frequency of both droughts and severe rainstorms can also destabilize annual crop yields. Because livestock are temperature sensitive, there are likely to be increased labor and maintenance costs to the farmer.

Now, let me talk about impacts on the places where we live and work in the Chesapeake Bay Watershed. The Virginia Institute of Marine Science estimates that sea level will rise between 4 and 12 inches by 2030. The Hampton Roads region of Virginia is the largest population center that is at the greatest risk from sea level rise outside of New Orleans. I mentioned frequent and severe coastal storms and flooding as an effect of climate change. The effects of these severe storms will be multiplied by rising sea levels, increasing risk to life and property. We also have to be concerned about salt water intrusion into groundwater supplies.

To be sure, we can adapt to a few of the impacts of climate change, but others will be devastating. It's difficult to predict how the impacts will affect one another, or what the endpoints of these impacts will be. We need additional research at a watershed level so that we can better prepare for the changes that are coming and take prudent steps to reverse the trends in greenhouse gas emissions we are now seeing.

Madame Chair, I state none of these facts to be alarming. I state them to show what is at stake if we don't face the challenges of climate change head on. I wish I could say that these impacts are only speculative, but they aren't. In Virginia, where we rely so heavily on the health of our natural resources for their economic, social, and historical value, we simply can't afford to postpone action any longer.

That's why my Administration is taking action. In April, I issued Executive Order 48, which requires state agencies to reduce the annual cost of non-renewable energy purchases by at least 20 percent of fiscal year 2006 expenditures by fiscal year 2010. And, in May, I announced that Virginia was joining the Climate Registry, which provides a forum for states to work together develop a common accounting system to track greenhouse gas emissions.

I also recently released a comprehensive Energy Plan for Virginia, which covers all aspects of energy production and consumption and calls for the state to dramatically increase its efforts in energy efficiency and conservation. The Plan identifies four overall goals, including reduction of greenhouse gas emissions by 30 percent by 2025, bringing emissions back to 2000 levels. Soon, I will announce the appointment of a Commission on Climate Change to prepare a Climate Change Action Plan to implement these recommendations. The Commission also will gather information on the expected effects of climate change on the state and identify actions that Virginia needs to take to prepare for the consequences of climate change that cannot be avoided. The Energy Plan also recommends that Virginia impose mandatory reporting requirements on emitters of greenhouse gases, and I will work with the legislature to implement this recommendation.

While these are important steps that we are taking at the state level, action on climate change must occur at the federal level. Many states are developing climate action strategies, but that does not forestall the need for congress to take action. Both the causes of, and solutions to, climate change transcend state and local boundaries.

Virginia stands ready to participate in the development of legislation that will reduce emissions of greenhouse gases nationwide. I support legislation that includes a cap-and-trade program for emissions of all greenhouse gases, imposes economy-wide controls, rather than singling out a particular sector, and accounts for state efforts to standardize methodologies to record and measure green house gas emissions through the Climate Registry.

I know that there are many ideas being discussed in your committee right now, and I thank Senator Warner for being a leader in this effort. My message to you is that each day that legislative action is delayed will have negative consequences for the Chesapeake Bay. I urge you to pass legislation that addresses climate change in a comprehensive way, as quickly as possible.

Once again, thank you for the invitation to be here today. I am happy to answer any questions that you may have.

Senator BOXER. Governor, thank you so much. I thought your ending was very appropriate because there was recently an article that said a lot of our treasures will be gone if we don't act.

Hon. Martin O'Malley, welcome, sir, Governor.

STATEMENT OF HON. MARTIN O'MALLEY, GOVERNOR OF THE STATE OF MARYLAND

Governor O'MALLEY. Madam Chair, thank you very much. Thank you very much, Madam Chair, Senator Warner, Senator Cardin, Senator Mikulski. It is a distinct honor and a privilege to be here with you today discussing this probably most critical of all moral challenges that face us as a people. It is also a great honor to be able to serve with someone of Governor Kaine's commitment and passion for the protection of our natural environment, and the tremendous asset and treasure that is the Chesapeake Bay.

That was a wonderful story about the settlers of Jamestown and our rediscovery of the fact that the place that they inhabited the first year is still there. It is within our grasp. There is so much history up and down the banks of the Chesapeake Bay, and I think one of the common traits that all of the settlers at Jamestown had, as did all of the people who settled in Maryland and on the Chesapeake Bay, is something that we still have, and that is a future preference, a preference for a better, safer and healthier future.

Certainly, as we look at this issue of climate change and rising sea levels, that is really going to put that great American in Maryland and Virginia idea to the test. Do we have the ability and the will and the courage to do what needs to be done in order to honor not only the inheritance and the hard work that we have received from others, but also to keep faith with posterity.

I wanted to, rather than recapping so many of the threats, I wanted to cut right to some of the things that we are doing as a State. Governor Kaine certainly, and Senator Mikulski and others outlined the threat of rising sea levels, the islands that are no longer visible; thousands and thousands of miles of coastline, and insurance companies no longer willing to write insurance for those risks.

I wanted to talk to you about the idea that we have found is helpful as we come together with human will and human action to apply to this problem. And that is a shared vision of sustainability, sustainability of the land we use, the water we use, the air, because of the energy we consume, the air that we use. In Maryland, as Senator Mikulski mentioned, we have implemented a new program called BayStat, where we pulled the Department of Agriculture at the State, and the Department of Environment, and scientific minds and academics and practitioners around the table every 2 to 3 weeks, looking at a common map of our interactions, of the synergies, and the things that we do together to implement

those things which we know will make a difference towards meeting the goals we have for a cleaner and healthier bay.

But when it comes to the air we consume, which is absolutely affected by the energy we consume, in Maryland we are implementing an ambitious, but achievable vision that we produced in collaboration with other neighboring States, to reduce greenhouse gas emissions. Together, we established the Regional Greenhouse Gas Initiative, a working partnership between 11 States to reduce greenhouse gas emissions from the power plant sector. Together, we fought for and we passed the California clean car standards, which will require cleaner, more fuel-efficient cars in our State by 2011. Together, we created the Commission on Climate Change this year, charging their professional membership to prepare Maryland's plan of action. Together, we set a goal to reduce our per capita electricity consumption by 15 percent by 2015.

Together, we are diversifying our energy portfolio with clean renewables like solar, wind, biodiesel, and biomass. We have started by adopting one of the most aggressive laws in the Nation requiring two percent of Maryland's electricity, or approximately 1,500 megawatts, to come from solar by 2022.

With the help of Senator Mikulski and Senator Cardin, we are going to continue to lead, and we intend to have the first long-range plan to address the coastal changes caused by climate change.

Why do we do this? For two very important reasons: No. 1, is necessity; and No. 2, is what I began with, that future preference, that obligation that we have to come together across manmade borders because of the nature of this challenge which recognizes no borders. It calls upon all of us to come together for ourselves and for our posterity.

Other States are also stepping up to the plate. Currently, 26 States have taken concrete action on climate change. Over 20 States have set substantial greenhouse gas reduction targets. Using State efforts as a model, there are many programs that can radically reduce greenhouse gas emissions at a reasonable cost.

But as Governor Kaine said, we cannot go it alone. We need the partnership of our Federal Government. There is a long, proud history of Federal leadership on environmental and conservation issues, from the days of Theodore Roosevelt in the very first national parks, to the Clean Air Act. We need our Federal Government. Together, we can develop national programs that tackle greenhouse gas emissions. We can transform our Nation from a carbon-based economy to a green, sustainable economy.

The time to act is past. The time to catch up is now. And we greatly appreciate the leadership of this Committee and our Congress in helping us protect the most important asset that we inherited from our parents, and that is the health of our natural environment in this great Country.

Thank you very much.

[The prepared statement of Governor O'Malley follows:]

STATEMENT OF HON. MARTIN O'MALLEY, GOVERNOR FROM THE STATE OF MARYLAND

Madame Chair, Ranking Member Inhofe, and distinguished Members of the Committee, it is my distinct honor and privilege to testify before you today about a global issue that has become a very real local issue today for the citizens of the great

State of Maryland. I would also like to give special thanks to Senators Barbara Mikulski and Ben Cardin, from my home state, for their extraordinary leadership and help in bringing about this opportunity.

In Maryland, we have over 4,000 miles of coastline—4,000 miles—this is more coastline than the State of California. Maryland is in a very precarious position when it comes to the impacts of climate change. Our region is ranked third in the nation terms of our vulnerability to sea level rise. We are third, behind only Louisiana and South. In Maryland, climate change and sea level rise are at our doorstep.

While we are fortunate enough to hug the Chesapeake Bay, a fragile estuary, it also means for us that the impacts of climate change have already been detected. Historic tide-gauge records show that sea levels have risen one-foot within Maryland's coastal waters over the last century. Due, in part to naturally occurring regional land subsidence, the Chesapeake

Bay region is currently experiencing sea level rise at a rate nearly double the world-wide average.

There is now near universal scientific consensus that the world climate is changing. Scientists estimate that temperature will rise between 1.98–11.52 °F and that our sea level will rise as much as 7 to 23 inches over the next century. If left unchecked, these estimates will translate into devastating impacts for Maryland's citizens, its property, its bountiful natural resources, and the investments of its taxpayers.

Thirteen charted islands and large expanses of tidal wetlands within the Chesapeake Bay have already disappeared. Each year, the State loses approximately 580 acres of land to shore erosion.

Current scientific research indicates that the rate of sea level rise is starting to accelerate in Maryland waters. The result of such a rise will be a dramatic intensification of the impacts from coastal flood events; increased shore erosion; the intrusion of salt-water into our freshwater aquifers—any of which are used for potable water supply; and submergence of tidal wetlands, low-lying lands and even the Chesapeake's last inhabited island community, Smith Island.

In Maryland, we do not have time to wait. Nor would I suggest, does the country have time to wait. Climate change is perhaps one of the most daunting challenges facing Maryland. The time is upon us to take action to begin shaping our own future in the face of this threat. Decisions we make today will influence Maryland's health and vitality long into the future.

We now know with certainty that human activities—including coastal development, the burning of fossil fuels and increasing greenhouse gas emissions—are contributing to both the causes and consequences of climate change. In Maryland, as a State, we are implementing aggressive initiatives to reduce greenhouse gas emissions:

• We are a full fledged member of the Regional Greenhouse Gas Initiative—a voluntary collaboration of 11 states to reduce greenhouse gas emissions from the power plant sector.

• We have adopted the California Clean Cars standards which will require cleaner and more fuel efficient cars in our state by 2011.

We have established a Commission on Climate Change and have charged this Commission to recommend Greenhouse Gas Reduction Goals and to prepare Maryland's Plan of Action.

• We established a goal to reduce our per capita electricity consumption by 15 percent by 2015.

• We are diversifying our energy portfolio with clean renewables like solar, wind and bio-diesel and bio-mass, and have recently adopted one of the most aggressive laws in the nation to require two percent of Maryland's electricity, or approximately 1,500 megawatts of power, to come from solar energy by 2022.

Maryland will continue to be a leader. We intend to be the first state in the nation to develop a long range strategy to plan for and adapt to the changes we will face along our coast caused by climate change. Many have asked why a small state like Maryland would take these actions. The answer is, first, because we have an immediate problem. Second, Honorable members of the Committee, it is the right thing to do. We know that the best way to address this issue is with global action. The next best—is acting country-by-country, as over 160 of our fellow nations have done. The next best option is to take action state by state.

Maryland will continue to be a leader. With the help of Senators Mikulski and Cardin, we will continue to do what is right for our state. Third best, however, is simply not good enough. We need our federal government to act. State-by-state reductions simply don't make sense for this global problem and the time is now for federal action on climate change issues.

We have a long history with environmental challenges in this country. Many challenges are local and are appropriately dealt with at the state level. But on national issues, we seem to go one of two ways. The federal government enacts laws, develop standards, and the states follow and implement. Or, when the federal government fails to lead, states have no choice but to step up and act This appears to be one of those occasions.

Currently, 26 states have initiated actions related to climate change. Over 20 states have set substantial greenhouse gas reduction targets. Using the state efforts as a model, there are many programs that can radically reduce greenhouse gas emissions at a reasonable cost. The time has come to develop national programs that effectively reduce greenhouse gas emissions from fossil fuel burning power plants, from our automobiles, and a multitude of other sources.

We must transition from a carbon-based economy to a green, sustainable economy—an economy that does not prolifically emit greenhouse gases into the atmosphere as a byproduct of progress. Economic progress at the cost of environmental sustainability is not progress at all.

Furthermore, we must proactively plan for the consequences of climate change by amending coastal zone management plans, integrating the consequences of climate change into federal programs for flood and shoreline management. Federal agencies should be coordinating to ensure that we adapt to climate change as a nation.

When given a choice between progress and regression, the people of Maryland always choose progress. We have an unshakeable belief in what Carroll Quigley, a historian at Georgetown, called "future preference"—the idea that "tomorrow can be better than today and that each of us has a personal and moral responsibility to make it so." Why is sustainability so important? Because, as the old Native American proverb goes, "we do not inherit the Earth from our ancestors; we borrow it from our children."

Why we are so concerned about energy efficiency and placing an emphasis on "green?" Because, in the words of Maryland's Own. columnist Thomas Friedman: "the people who will be harmed the most by the climate-energy crisis haven't been born yet."

Public service is about making decisions, many for which the consequences will be felt long after we're gone, many for which we may not be around to enjoy the benefits. In the short time we have in these jobs, jobs, and on this earth for that matter, let's resolve to put aside the impulse for instant gratification . . . and instead, embrace a compact with the grandchildren who are yet to be born.

In the finest American tradition, let's prefer their future over our present . . . forsaking patchwork quick-fixes for enduring solutions. Let's do for them what the Greatest Generation and our forefathers did unflinchingly for us—relinquish the comforts of today in the name of a better tomorrow.

Climate change is one of the most pressing challenges facing our generation today—we must, and we can, collectively find a way ultimately to address the problem to achieve sustainability, as a State and as a Nation.

Thank you very much for your time in considering my testimony today.

Senator BOXER. Thank you so much, Governors. We will each have five minutes for questions, if you don't mind. Can you stay a little bit longer? OK.

I wanted to pick up, Governor Kaine, when you talked about the fact that you had military assets along the coast and coastal areas, because I find it so interesting that Senator Warner, teaming up with Senator Lieberman, is really in the lead in this entire Senate now. One might say, well, this is unusual; here he is, an expert on military matters, and here he is taking the lead. But there is a marriage between the two here.

I mean, we have received warnings from our own intelligence people and our military people that if we don't act on global warming, it will be the major cause of wars in the future, the major cause of refugee dislocations, famine, drought, which cause wars.

So in many ways, you are bringing up the fact that the assets that are along the coast brought that to my mind, that this marrying up between the environment and our national security is so interesting and that Senator Warner is here at this time. It is to me a very moving point.

I had one question for both of you, and that is this. In order to effectively address global warming, we are being told by our business people very clearly that they need to have clear market signals, that what we do here is real. So that when we set our goals, they are real, and there are not big loopholes where people can drive off and say, "All right, we don't have to do anything about carbon anymore or greenhouse gases."

So are you hearing similar things in your States? Because in my State, which, like you, California has taken a major lead on this, and our Governor, Governor Schwarzenegger, working with our Attorney General Jerry Brown and the legislature, has been just a model in terms of how they have acted here.

So do you hear similar points being made, that we need to act with clarity so that the investments in new technologies will in fact come to fruition? If either one of you wishes to respond.

Governor KAINE. Madam Chair, those are signals I am hearing from my private sector. And on a couple of sort of related points, first, the clarity of the signal for an investment climate is key. The good news is investments across the range of alternative energy sources and conservation that weren't particularly powerful 5 years ago suddenly are hot. So there are some good market signals out there already to promote this.

The other issue that I am hearing related from my private sector folks is the approach that needs to be taken on climate change should be across all industries. Don't just focus on one or two industries. For example, in Virginia we know one of the huge challenges we have is a lot of the challenges are from transportation, vehicles, transportation modes that need to be upgraded. So we shouldn't just focus on power plants and then sort of let transportation off the hook. It needs to be something that is truly across all industry sectors. That is also what I hear from our private sector folks. It needs to be comprehensive and not single folks out.

Senator BOXER. Thank you.

Governor O'Malley.

Governor O'MALLEY. We have been working cooperatively with our power industry in our efforts to join REGI and our own cap and trade. We hope to have our first auction in the summer of 2008. While we have been working cooperatively with them, I have to say that I have yet to talk with a person from the power industry that doesn't believe that a national program would be far preferable, instead of a patchwork of hopscotching, one State does, one State doesn't.

The industry itself wants predictability. They want sustainability, clear market signals, as you said, Madam Chair. They also want a national program.

Senator BOXER. Thank you, sir.

Senator Warner.

Senator WARNER. Madam Chairman, I think I would like to yield my time to our distinguished colleague from Maryland, my good friend, Senator Mikulski. Oh, no, I insist. I have that right as Ranking that you go now.

[Laughter.]

Senator WARNER. Now, I stop to think. We are seated here with these two great Governors of our States. One hundred years ago,

they used to have wars in Chesapeake Bay between the oystermen and the crabmen and the rockfish. And here we are sitting peacefully talking about a common endeavor. It is very refreshing.

Senator Mikulski, keep a watchful eye to prevent those wars reoccurring.

[Laughter.]

Senator WARNER. Senator, I yield to you.

Senator BOXER. Senator, please go ahead.

Senator MIKULSKI. Well, thank you very much, Senator Warner. I know you had to step out at the beginning of the hearing, but what I said was that you have really been a champion and a real warrior. You have protected this Nation, both by putting yourself directly in the line of fire as a warrior against those who had a predatory intent towards the United States of America. And now, along with that, you are really making sure that part of your incredible legacy is that you are protecting the very planet and the very bay that you love.

We want to really work with you on your environmental legislation, but for this Senator it has been indeed a great pleasure to work with you on the issues related to Maryland and to Virginia. Having said that, I accept your gracious invitation to ask a few questions.

I think we are all clear listening to our two very dynamic Governors that patchwork doesn't work. Now, one question will be not only what you will need from the Federal Government in terms of standards, et cetera, but you each are going to have—Governor O'Malley already does and Governor Kaine you will—these Commissions on Climate Change. I know with the knowledge economy that we both have, as well as the practicality of agriculture, the watermen economy, et cetera, could you share with us what we can expect from the Governors to provide guidance to the Federal Government on what we need to do? We need to help you have a national program based on sound science that you can work with funding great laboratories like the Virginia Institute and our own University of Maryland Laboratory work.

But what could we expect from these commissions that would give us guidance?

Governor KAINE. Well, as was pointed out, Governor O'Malley has created a commission. I just have announced the creation of one, so we are putting one together. The good news, Senator, is that we have a deep talent pool of scientists and advocates who are very, very engaged in this. We know already that sort of as a State policy we would support a national cap and trade program. I believe that without saying what the commission's recommendations would be, there is strong support for that in Virginia and I suspect would come out of a commission in that sense.

In addition, we do have good research institutes. The Virginia Institute of Marine Science, and Virginia Tech does significant research on carbon capture and storage in the southwestern part of the State. We have a number of other research universities that do significant work in this area. They will be part of the commission.

So I think one of the things that we can do as Governors and with these commissions is forward the research that is being done. It is just a matter of harvesting what is there already in terms of

strategies. I think we will have some very good recommendations that we can get to you from the talent pool that we have in Virginia.

Governor O'MALLEY. I suspect that the recommendations from Maryland's Climate Change Commission are probably going to break down in about four different parts. There will probably be recommendations on how we prime, encourage, move more quickly towards diversified portfolios in terms of the energy we use. Energy-efficient buildings—we have all become accustomed to understanding how much power plants and cars emit, but there is tremendous opportunities to reduce our carbon footprint, and I suspect they will be making recommendations on energy efficiency in buildings.

Thirdly, the cap and trade, which we already mentioned, I would have to believe that they will come out with recommendations for a national program on that score. And finally, transportation—the way we get to and from. Another important part that I think Maryland is particularly sensitive to, maybe in advance of some other States and certainly parts of Tidewater Virginia experiences this as well, and that is the connection between land use and global warming. In other words, our population has increased by about 30 percent since the 1970s, but the land we consumed has increased by about 100 percent. With that comes a tremendous amount of impervious surface, a lot more lane miles traveled, and everything else that goes with that.

So I suspect that Maryland's Climate Change Commission will also have recommendations on what we can do and where the connection between land use and climate change is becoming more and more apparent.

Senator MIKULSKI. Thank you. I note that my time is up. I would hope that one of the things that we could get, particularly from Maryland and Virginia, would be recommendations related to energy, and especially transportation. Both of our States have terrible transportation issues. I know Virginia has grappled with it from a reliable revenue stream to do this, but when we look at everything from the mixing bowl to our turbo car door, we all know that transportation is the number one issue with our constituents.

But also then how can we turn this lemon into a new lemonade stand? Meaning, what can we do to look at our energy policy as well as our transportation policy that, number one, deals with global warming, helps solve transportation problems, and create markets for new types of vehicles, not only passenger vehicles, but as Governors you know, how about the cost of school buses? How about the cost of your own transportation fleets? To actually make the Federal Government a partner with you, that is you go to buy mass transit vehicles, how we can have incentives to go to green vehicles that would help the so-called market cues.

So we look forward to working with you. I am glad that we have put aside the oyster wars and I am ready for an oyster festival. So thank you very much.

Senator BOXER. Thank you, Senator.

Senator Warner has told me that he would like Senator Cardin to go next. So our amazing colleague is again deferring, so Senator Cardin, the floor is yours.

Senator CARDIN. I add my thanks to Senator Warner. Senator Warner, as I mentioned when you had left, has been one of the real champions. The beginning of the Federal Government's involvement in the Chesapeake Bay was the result of the leadership of two great U.S. Senators, Senator Warner and Senator Matthias. They took that on, and Senator Sarbanes joined them, and we have the involvement today as a legacy of Senator Warner, but he is going to do something else before he retires.

He won't retire before he leaves the Senate, and that is he is taking on the leadership on global warming. We thank him for that because he is going to I think give the type of sage advice that gives us the best chance of getting a bill enacted. We thank you for your continued leadership, and I thank you for your courtesy and for your help as a member of the U.S. Senate.

I agree that a piecemeal approach won't work on these issues, so we do need the Federal Government involvement. But I do think we can learn from the States. That is what federalism is about. So I really congratulate the leadership of both of our Governors here because you are giving us workable models that we can now use as national policy.

Governor O'Malley, I know that your leadership in dealing with conservation and renewable energy sources has been just dramatic, and we thank you for that. This week, we held a hearing in this Committee on the economic advantage of green policies. We had testimony from Marylanders on solar energy, and our State is one of the leading sources now of solar energy development. My question to you is, have you evaluated the impact of your policies on the economy of Maryland and the reaction you are getting from the business community as you look towards ways of getting less electricity use, energy use in our State, and looking at developing a wider portfolio of energy supplies in Maryland?

Governor O'MALLEY. Well, certainly our hope, Senator, is that as a Nation that has a very strong knowledge-based economy, as a people who have always been innovating and creating new jobs every generation, it is certainly our hope that as we develop new sources of energy, as we apply our minds and the diversity of minds that we have in our State to this challenge that there is a whole wealth of jobs that can be created by throwing ourselves into green building technologies, renewables, and energy efficiency.

We have really been engaged in days and days of conversations with stakeholders as to how we throw ourselves into energy efficiency. However we go about doing it, it is unavoidable that it will require a lot of skilled and well trained people who will have to work here in Maryland in order to create whether it is a smart grid, whether it is smart meters in homes, the creation of energy-efficient appliances and the like.

So I think this could be a great new wave for our State and for our Country, the mixing both of high-minded, innovative, cutting edge technology, but also the sort of hands-on skilled jobs that put food on a family's table and bring about the security and prosperity that is the mark of any progress.

Senator CARDIN. Thank you.

Governor Kaine, I also want to join the Chairman in just appreciating the way that you brought in national security to this de-

bate. I hadn't thought about Hampton Roads and realized it was the second most vulnerable city or area to flooding, and the huge population center that is there. But it is of critical importance to our national defense.

The additional risk we are putting on national defense, where we could do something about it, with extreme weather and the dangers. I very much appreciate your bringing that up, because that point has not been brought out in our discussions on global warming. I think it is an extremely important point and one that we should follow up on, Madam Chair, as part of our work.

I also appreciate your testimony as to the quality of life, so many factors involved with the Chesapeake Bay and how it really makes Virginia a unique place to live and work.

Madam Chair, I just want to bring to the committee's attention the report that was released today by the National Wildlife Federation, the Chesapeake Bay and Global Warming. It points out some of the points that we have already talked about, that global warming threatens an already beleaguered Chesapeake Bay. We don't deny it. We have problems in the Bay. But global warming is making it more challenging.

It also talks about another part, and Congressman Gilchrest mentioned this, gone fishing or fishing gone. This report says that the Chesapeake is becoming too warm for winter flounder. We are liable to lose it altogether. And soft clams we are liable to lose altogether because the winter is just too warm. If it is appropriate, I would like to see this as part of our record.

Senator BOXER. Without objection.

[The referenced document follows on page 88.]

Senator CARDIN. Again, I thank our Governors for being here.

Senator BOXER. Senator Warner.

Senator WARNER. Thank you, Madam Chairman.

I would like to follow on one of Senator Cardin's themes, and that is the impact on the economy. Under the strong leadership of our Chair here, we had a hearing yesterday that was quite interesting. We are all quite familiar with the term "blue collar," the people who get out there and sweat and work and make our economy what it is today in large measure, under the direction and framework of executives on top.

But we have a new term coming up. It is called "green collar." I thought we had a convincing body of fact given to the Committee yesterday about how the collective efforts of the several States, together with the Federal Government, towards the climate change remedies are creating an entire new class of citizens who proudly work in what we call green collar jobs, namely erecting the wind power stands and dealing with all of the other aspects of the initiatives that each of you have taken in your States.

I wonder if you would lead off, Governor Kaine, followed by Governor O'Malley. Are you beginning to categorize these jobs and relate that to the citizens of our great State? Because I have always said from day one in my efforts on this subject, there is going to be added costs at the gas pump when you go and fill up your car. There is going to be an added cost when the homemakers have to pay that monthly heating bill. A lot of these costs of the industrial

and the manufacturing and the transportation levels are being fed right back to the consumer.

So I think it is helpful to try and show the balance, the creation of a new category of jobs.

Governor KAINE. Senator Warner, Virginia is the number one State in the Nation in the percentage of our workforce that work in technology jobs. We have seen in the last 3 or 4 years a definite anecdotal increase in the number of technology jobs in alternative energy and energy sectors. I just think of a very large Virginia company right across the river, AES, that does energy around the Nation and around the world. They are one of the largest producers of wind power in America right now. They produce alternative energy at facilities all around the United States and the world at this time.

So we are seeing that green collar sector of the economy. I had not heard that phrase, but we are seeing that grow. It often clusters around the research institutions. We have a Coastal Energy Research Consortium at Old Dominion University with a lot of private sector involvement, including many contractors that work on the military installations in Hampton Roads. We have similar energy research going on, primarily on the coal side, clean coal down at Virginia Tech.

So we do see these technology jobs grow in this area. I will also say this, and this is some good news. The traditional blue collar industries are not our opponents in this in Virginia. They have some questions. They have some challenges. They participated in a yearlong effort to put together this energy plan we just released, but the overwhelming number of the recommendations we made were with the environmental community and the manufacturers association on board.

Ag and forestry is the biggest industry in Virginia. Global climate change dramatically affects the largest industry in Virginia, ag and forestry. Tourism is one of the largest five industries in Virginia. If we do not do something about this, the traditional industries that have been the bulwark of the economy up to this point are seriously jeopardized.

So both the old economy industries and these new green collar opportunities have folks aligned with the notion that this is an important task that we should tackle.

Senator WARNER. Good.

Governor O'Malley.

Governor O'MALLEY. We have not gotten to a point, Senator, where we are actually very good at categorizing these things, but we see them developing and happening around us. I think they have been in proportion to the clarity of this clear market signal. For example, we adopted one of the larger solar requirements in our portfolio and BP Solar in Frederick around that same time announced that they were going to double the size of their plant and their employment out there in Frederick.

It is actually very exciting when you think about the new jobs that can be created, and just how much we have to do to align our workforce development, the sort of career technology training that we should be doing along with algebra two in our high schools and creating those pathways in our community colleges. Community

colleges are probably going to beat everybody to the punch on this because they are more nimble and get out in front of these things.

We have a brave new world in front of us and look forward to aligning those, you know, capturing the opportunities that will come along with the some of the discomfort and additional cost.

Senator WARNER. Good.

Perhaps the Chair could ask our staff to provide these two distinguished witnesses with a little synopsis of the testimony that we had yesterday, and some copies of it, because I think it would be a great help.

Senator BOXER. Will do.

Senator WARNER. Both of these gentleman are quite busy in their respective full-time jobs, so I think I will yield the floor and let them return to their respective States, unless you want to talk a little bit about the football standing between Maryland and UVA.

[Laughter.]

Senator WARNER. How is that going, Governor Kaine?

Governor KAINE. We will see.

Governor O'MALLEY. We will get to the oyster wars.

[Laughter.]

Senator BOXER. Governors, I thank you so much. I just want to particularly thank Senator Warner for his graciousness. I want to just say that the Governors we are hearing from, Senator Warner and other Senators, are from both parties. Today, we happen to have two Democrats, but I have heard from, of course, Governor Schwarzenegger, who has provided terrific leadership on this, and also Governor Crist of Florida, who is continually writing to us. And there are other Governors from both parties. I don't want to start naming all of them.

But I think it just shows that the States are ahead of us here. We have a lot of catching up to do, and I think the two of you have made a very powerful case and tied it to the Bay, which is so important because we can see it, feel it, and touch it. And so we thank you very, very much. Any ideas you have will be welcomed in the future. Thank you.

Governor KAINE. Thanks, Madam Chair.

Senator BOXER. And now we would invite up our third and final panel, while the Governors are leaving.

William Baker is President of the Chesapeake Bay Foundation; Dr. Christopher Pyke, Member, Chesapeake Bay Program's Scientific and Technical Advisory Committee, and Fellow, Virginia Institute of Marine Science's Center of Coastal Resources Management; Dr. Donald F. Boesch, President, University of Maryland Center for Environmental Science; Dennis Avery, Senior Fellow, Hudson Institute, Director, Center for Global Food Issues; Dr. David W. Schnare, Esquire, Senior Fellow for Energy and the Environment, Thomas Jefferson Institute for Public Policy; and Pastor Richard Edmund, United Methodist Churches of Smith Island.

Gentlemen, we welcome you. We are very honored to have all of you here. We will go from Mr. Baker all the way this way, and we will try to keep it five minutes. I know we have a lot of questions.

Mr. Baker, welcome, the Chesapeake Bay Foundation. We welcome you.

STATEMENT OF WILLIAM C. BAKER, PRESIDENT, CHESAPEAKE BAY FOUNDATION

Mr. BAKER. Senator Boxer, members of the Committee, Senator Mikulski, thank you for your leadership over these many years. My name is Will Baker. I am President of the Chesapeake Bay Foundation. On behalf of our 194,000 members, we thank you for the opportunity to testify.

Senator Warner, special thanks to you for your years of support for programs to help Chesapeake Bay and especially for your generous support of that 30-year-anniversary tour with Senator Matthias—our great mutual friend and a founder of the Chesapeake Bay Foundation. I truly appreciate all that you have done over these many years.

Many thanks as well to Senator Mikulski and Senator Cardin, Senator Webb, who was here previously, and Congressman Gilchrest, and our two esteemed Governors, Governor Kaine and Governor O'Malley. We are so lucky to have you fighting for, as we heard, not against each other, fighting for the Chesapeake Bay.

Sadly, the Chesapeake Bay is in deep trouble. By any measure, it is only functioning at about 30 percent of its historic potential. Eighty percent of the Bay and its tidal tributaries are on EPA's dirty waters list. Think of it. A national treasure so rich in history and so valuable to our regional economy in such trouble.

Pollution is at the root of the problems. But now, global climate change is making matters worse. As the waters warm, they hold less dissolved oxygen, dangerously less dissolved oxygen. These waters are called "dead zones" and they plague the Bay. While the phenomenon is happening worldwide, it is worse in the shallow, slow-flushing coastal areas like the Chesapeake. Sadly, these waters are some of the most productive on earth. We are damaging the very nurseries that produce the fish and shellfish that we value so highly, like the Chesapeake Bay blue crab, to name just one.

Warmer water itself adversely affects the fish and shellfish. Striped bass, for instance, cannot tolerate water that is 76 degrees or warmer, so as surface waters warm, they dive deeper to try and find cooler waters, only to be blocked by the deep water dissolved oxygen-starved dead zones. They are being squeezed from the top and the bottom and stressed, and the result is greater susceptibility to disease.

Another real threat is to eelgrass. I know this is especially important to Senator Warner because it is the predominant Virginia species of underwater grasses. At 80 degrees, it simply dies, and we are seeing 80 degrees in the southern Bay all too often. No underwater grasses, no crabs, no fish, no shellfish.

Unfortunately, some Bay species appear to benefit from warmer water. I say "unfortunately" because those species are the nuisance algae, some of which are toxic. One especially noxious species of algae was plaguing the Norfolk and Hampton Roads area for much of the summer. One last impact: sea level rise combined with an increase in storm intensity will mean more floods, more erosion, more polluted runoff, more damaged wetlands. None of this will be good for water quality or human health or recreation.

There is some good news, however, and this time it really is good news. A primary strategy to reduce the nitrogen that is so polluting

the Chesapeake Bay is to help farmers install conservation practices on their land. The reason I bring it up at this hearing is because these practices, if implemented, will sequester a minimum of 5 million metric tons of carbon, the equivalent of taking over 750,000 Hummers, each driving 12,000 miles a year, off the road. Exceptional, exceptional result.

So here is the win-win-win: help farmers stay on the land; reduce nitrogen and carbon; increase dissolved oxygen, a tremendous benefit for the environment.

In closing, let me thank you and urge support for a cap and trade bill such as that which Senators Warner and Lieberman are developing. And let me urge support for a specific provision of that bill, which I understand will be in the legislation, that which will help provide funding for the great waters of the United States of which the Chesapeake Bay is certainly one. A national treasure, the birthplace of our great Nation, will thank you, and I thank you.

[The prepared statement of Mr. Baker follows:]

STATEMENT OF WILLIAM C. BAKER, PRESIDENT, CHESAPEAKE BAY FOUNDATION

Chairwoman Boxer, Senator Inhofe, Senator Warner, Senator Cardin and other distinguished members of the Environmental and Public Works Committee, I am William C. Baker, President of the Chesapeake Bay Foundation. Thank you for inviting me, on behalf of CBF's board, staff, and 190,000 members, to participate in today's hearing.

I want to particularly acknowledge Senator John Warner for the work that he has done to improve the health of the Chesapeake Bay during the nearly thirty years that he has represented the people of the Commonwealth of Virginia. Even though the Bay still has many challenges, it is much better off than it would have been without Senator Warner's strong interest and effective assistance during all those years. Although he has announced his retirement at the end of this Congress, this hearing and the development of the Lieberman/Warner legislation are indications that he's a long way from being done. Senator Warner, thank you.

Moreover, although none of them is retiring—in any sense of the word—I also want to acknowledge the tremendous work done that Senator Mikulski, Senator Cardin and Congressman Gilchrest are doing here in Congress on behalf of the Bay. All three are doing everything they can to restore the health of the Bay, and I know they will continue to do so for many years to come.

For more than 40 years, the Chesapeake Bay Foundation has been working to protect and restore the Chesapeake Bay. The Chesapeake Bay is America's largest estuary, and its 64,000 square mile watershed—from Cooperstown, New York to Cape Henry, Virginia and westward to the Allegheny Mountains—is a large part of the Mid-Atlantic states. More than 17 million people live in the Chesapeake Bay watershed, a number that is increasing by roughly 150,000 each year.

If you follow the Chesapeake Bay Foundation's annual State of the Bay report, you know that the lack of progress being made to improve water quality and protect the living resources of the Chesapeake Bay continues to cause very serious concern. The numeric score that our scientists calculated last year to represent the overall health of the Chesapeake Bay—29 on a scale of 100—is only one point higher than it was in 1999. This means that the Bay is ecologically functioning at between one-fourth and one-third of its historic capacity, and is not improving nearly as fast as we would like. The most systemic problem continues to be an overload of nitrogen and phosphorus pollution creating a lack of dissolved oxygen in many parts of the Bay and its tributaries. Every summer, the mainstem of the Bay and several of its tributaries are plagued by dead zones, where not enough dissolved oxygen exists to sustain many forms of aquatic life. The volume of water affected by these dead zones varies by year, but on average about 80% of the Bay and its tidal rivers have insufficient levels of oxygen.

The fact is that today's Chesapeake Bay ecological web is a pale reflection of what it was not so very long ago. Chesapeake Bay oysters, the great natural filter of the Bay's water, are currently less than 4% of their historic levels. The Bay's flagship species—the blue crab—is in such jeopardy that entire watermen communities are disappearing, and the great crab processing companies now survive on foreign imports. The underwater grasses so essential to life in the Bay are subject to massive

die-offs related to increased water temperature, and the Bay's wetlands, critical to thousands of species in its web of life, are being destroyed yard by inexorable yard.

We have become complacent about the constant, slow deterioration of one of the world's great natural resources. The degree of stress on the system from pollution flowing out of our cities and farms is enormous, and the system certainly does not need more stress. Yet additional stress is exactly what the Chesapeake Bay ecosystem is already getting from rising water temperatures and sea level rise. When CBF embarked on its mission to "Save the Bay" four decades ago, we had no idea that carbon dioxide and other greenhouse gases would be a huge threat to the people and other living resources that depend on the Bay for their existence. We understand now, however, that fossil fuels burning in Indianapolis or in India, as well as a host of other greenhouse gas producing activities, will negatively affect the people and creatures of the Chesapeake Bay just as toxics and other well-known pollutants do. The policy choices you and your counterparts in other nations make will determine how severe those negative effects will be and how long they may last.

I will just touch briefly on what scientists believe will be the effects on the Chesapeake Bay unless action is taken to dramatically reduce emissions and sequester additional carbon. I know that my colleagues on this panel from the scientific community will fill in the details.

WARMER WATERS

Ocean temperatures are rising, and the water temperatures in the Chesapeake Bay are as well. Warmer water has less capacity to hold dissolved oxygen, and dissolved oxygen is critical for most life in the Bay, its rivers, and its streams. Thus, higher temperatures may exacerbate the Bay's dead zones, potentially expanding both the size and the duration of oxygen-deprived areas in the Bay.

In one of nature's characteristic cycles, oxygen-deprived dead zones in the Chesapeake Bay and its tributaries can actually contribute to additional greenhouse gas generation. Globally, estuaries emit approximately one third of the world's oceans' net emissions of nitrous oxide, a very potent greenhouse gas. In the few places where it has been studied, nitrogen pollutant loads to estuaries have been shown to contribute to increased nitrous oxide emissions. Similarly, estuarine production of methane, another greenhouse gas, also increases under low-oxygen conditions due to bacterial activity, so the Bay, in its overloaded and degraded state, is actually contributing to climate change.

Changes in water temperature can also affect the distribution and health of aquatic species in the Chesapeake. For instance, adult striped bass, also known as rockfish, try to avoid water warmer than about 76 degrees Fahrenheit by finding refuge in the cooler temperatures of deeper water. During the summer, however, rockfish face what scientists call "temperature-dissolved oxygen squeeze," when dissolved oxygen concentrations in these waters drop past the point where adult rockfish can survive. With predictions of higher water temperatures and expanded dead zones, rockfish will be increasingly squeezed, forced to live in uncomfortably warm water in order to "breathe." Such stress can affect the health of fish by changing their feeding habits or making them more susceptible to disease.

Scientists still have much to learn about the effects of increased carbon dioxide and warmer water temperatures on the various types of algae found in the Bay, but it seems clear that some species, like the harmful algae Cochlodinium that plagued the Hampton Roads/Norfolk area last month, may prosper under the various climate change scenarios.

STORM INTENSITY

Although climate change models are as yet inconclusive about whether more precipitation will fall in the Chesapeake Bay watershed, or exactly what seasonal variations in precipitation may look like, most models agree that storms will become more intense. Storm intensity has an important impact on the Bay region in terms of property damage as well as on Bay's ecological health. Increased scouring and runoff from more intense rain events, regardless of season, will carry significantly higher loads of nitrogen, phosphorus, and sediment to tributaries, and thus to the Bay. Since it is this trio of pollutants that is primarily causing the continued decline in the Bay's water quality, additional heavy loads of them during more intense storms in the Mid-Atlantic states can be expected to appreciably compound the Bay's water quality challenges.

SEA LEVEL RISE AND FLOODING

With more than 11,000 miles of coastline, much of the Chesapeake Bay area, including some large population centers, lies very close to water level. Worldwide, the

Intergovernmental Panel on Climate Change predicts that sea level will rise between 8 inches and 2 feet by the end of this century. Many scientists consider those estimates to be conservative, evidence is mounting that ice caps and glaciers are melting at accelerated rates. If the trend continues, apparent sea level rise could be as high as several feet in the region by the end of the century.

Although sea level rise will affect many parts of the world, the Bay region may suffer even more. Why? Because, even as waters rise, much of the area is actually sinking due to geological processes that began during the last ice age. This combination of processes has resulted in approximately one foot of net sea level rise in the Chesapeake Bay over the past 100 years—a rate nearly twice that of the global historic average. As a result we are losing Tangier Island, Smith Island, and many other low-lying lands around the Bay. Thousands of acres of environmentally-critical tidal wetlands are now unable to trap sediments fast enough to keep pace with rising water levels.

In the future, the combination of several feet of global sea level rise, flat topography, and subsiding land mass could make the people who live here in the Mid-Atlantic region particularly vulnerable. Demographic modeling correlated to projected sea level rise suggests that hundreds of thousands of people in low-lying coastal or river valley areas, including in several cities, could fall victim to serious floods, and these storms are likely to cause the most damage to socially vulnerable populations within the region. For example, a 2005 report by the Center for Integrated Regional Assessment defines areas within Hampton Roads that have high "numbers of children and elderly, and with a high number of mobile homes" as vulnerable. By a wide margin, these at-risk communities are the most likely to face severe flood and storm damage. Additionally, these storms—which are also predicted to increase in intensity—will not only increase demands on emergency services and rescue facilities in these areas, but literally flood those facilities as well. Essentially, those with the fewest resources to recover from a catastrophic storm will be among those hardest hit.

Clearly, the enormous challenge of reducing the effects of excess carbon dioxide and other greenhouse gas emissions requires a multiplicity of actions at every level of society to reverse our current destructive course.

One important way to improve water quality in the Bay and help to reduce the effect of greenhouse gas emissions is to maximize the use of common agricultural conservation practices to prevent nitrogen and phosphorus from running to the Bay while at the same time sequestering carbon. The Chesapeake Bay watershed states have already defined agricultural conservation as a key tool to achieve the pollution reductions necessary to remove the Chesapeake Bay and its tributaries from the Clean Water Act's 303(d) list. As part of the Chesapeake 2000 Agreement—a pledge to cut the amount of nitrogen, phosphorus, and sediment pollution discharged into the Bay and its rivers—Pennsylvania, Maryland, Virginia, Delaware, West Virginia, New York and the District of Columbia have each developed river-specific "tributary strategies" to achieve targeted pollution reduction goals. Region-wide implementation of these plans' agricultural components would reduce the excess nitrogen entering the Bay by nearly 65 million pounds annually—approximately 60 percent of the reduction needed to restore the Bay and its tributaries.

A recent Chesapeake Bay Foundation report entitled "*Climate Change and the Chesapeake Bay: Challenges, Impacts, and the Multiple Benefits of Agricultural Conservation Work*", drawing on a study conducted at the Yale School of Forestry and Environmental Studies, made the case that more widespread use of common agricultural practices such as planting winter cover crops, establishing riparian buffers, and practicing rotational grazing and no-till farming can help to sequester carbon while at the same time moderating the effects of adding greenhouse gases to the atmosphere. The Yale study estimated that approximately 4.8 million metric tons of carbon dioxide would be sequestered annually—the equivalent of mitigating the carbon dioxide emissions from residential electricity use across the state of Delaware. On a state-by-state basis, the greatest carbon sequestration benefits would be accrued in Virginia—approximately 2.3 of the 4.8 million metric tons. This large share is due to the prevalence of forest buffers and restoration programs in the Commonwealth's tributary strategies. In Pennsylvania and Maryland, carbon benefits would come from a broader combination of conservation practices.

I am aware that farm bill reauthorization is not within the Environment and Public Works Committee's jurisdiction. However, within the next few weeks, each of you will have an opportunity to influence the language of the farm bill on the Senate floor, providing you with a powerful opportunity to enhance the mitigation of greenhouse gas emissions as you work toward more comprehensive solutions. Providing additional technical and financial assistance to farmers to increase the use of common conservation practices such as cover crops and buffers is a win-win strategy

for the Chesapeake Bay, as well as for the global atmosphere. In fact, enhancing carbon sequestration on America's agricultural lands should be given more prominence as an objective of federal farm policy nationwide.

As I near the end of my statement, I want to focus particular attention on one element of the cap-and-trade bill that Senators Lieberman and Warner are developing. According to discussion papers I have seen, the Lieberman/Warner bill will allocate 24% of the proposed National Emission Allowance Account to the Climate Change Credit Corporation, rising to 52% over time. These allocations will be auctioned and the proceeds will be used for various purposes, including 10% to help mitigate the impacts of climate change on terrestrial wildlife and aquatic wildlife in the nation's great waters.

Certainly there are many potentially important uses for the funds produced by the climate change credit auction, but I want to encourage you to make sure that a significant share of the proceeds goes to projects that will help us to protect and restore the great multitude of plants and animals that we are destroying through our thoughtlessness—or worse. We are causing great harm to the natural world through the actions that we take in the service of our prosperous lifestyles. It is only appropriate that we do our best to compensate. And, as I have outlined today, the Chesapeake Bay ecosystem, already on the brink, will be harmed even more by global climate change. It is critical that some of the proceeds from the credit auction go to the nation's great waters, including the Chesapeake Bay, to address the impacts we are discussing here today.

In conclusion, I want to simply reiterate that the Chesapeake Bay, an ecosystem in serious trouble, will be subject to very significant additional stresses in the coming years from the effects of global climate change. There is much we do not yet know, and a great deal of what will happen to the Chesapeake Bay depends on the actions that you and other policymakers choose to take, but the outlines are very clear. I urge you to work hard over the next few weeks for a 2007 farm bill authorization that allows farmers more ability to address the Bay's nitrogen and phosphorus problem while at the same time sequestering carbon. As has already been recognized by the House of Representatives, the Chesapeake Bay watershed is a perfect national pilot area to simultaneously address water quality and carbon sequestration. Above all, I urge to you quickly consider and pass an aggressive cap-and-trade bill that will begin to force dramatic emissions reductions and provide a source of funds to help address the changes that we are already seeing in the Chesapeake Bay ecosystem.

Thank you once more for the opportunity to be here today. I am happy to answer any questions that you might have.

RESPONSES BY WILLIAM C. BAKER TO ADDITIONAL QUESTIONS FROM SENATOR CARDIN

Question 1. In the report on Climate change that CBF released earlier this year, you make the point that the actions we take to reduce the emissions will also have a positive, immediate impact on the Chesapeake Bay. Would you please take a moment to explain to the Committee the relationship between nitrogen and oxide pollution, global warming and current Bay restoration efforts?

Response. As you note, one of the purposes of our report on climate change was to highlight that many of the actions needed to reduce nitrogen pollution and restore water quality in the Chesapeake Bay will also lead to reductions in greenhouse gas emissions (and vice versa). 1 will give three examples of these dual benefits.

First, watershed-wide about one-third of the nitrogen pollution to the Chesapeake comes from the air, much of it in the from of nitrogen oxides (NOx), a group of compounds formed from the combustion of fossil fuels. Nitrous oxide—one of the "family" of nitrogen oxides—is a very potent greenhouse gas. In addition, as we know, the combustion of fossil fuels accounts for the majority of the carbon dioxide that is emitted in the U.S. Consequently, actions that reduce our combustion of fossil fuels (e.g. energy conservation and efficiency, renewable energy, fuel efficient cars) will have multiple benefits, including: (1) a reduction in nitrogen (NOx) pollution to the Bay, and (2) a reduction in the emissions of the greenhouse gases nitrous oxide and carbon dioxide, to the atmosphere.

Second, a major source of nitrous oxide is agricultural fertilizer use One of the strategies to reduce nitrogen pollution to the Bay is the adoption of enhanced nutrient management practices by Chesapeake Bay farmers. This measure will result in less fertilizer use which, in turn, will lead to reduced emissions of nitrous oxide into the atmosphere and less runoff of nitrogen fertilizer into the Bay.

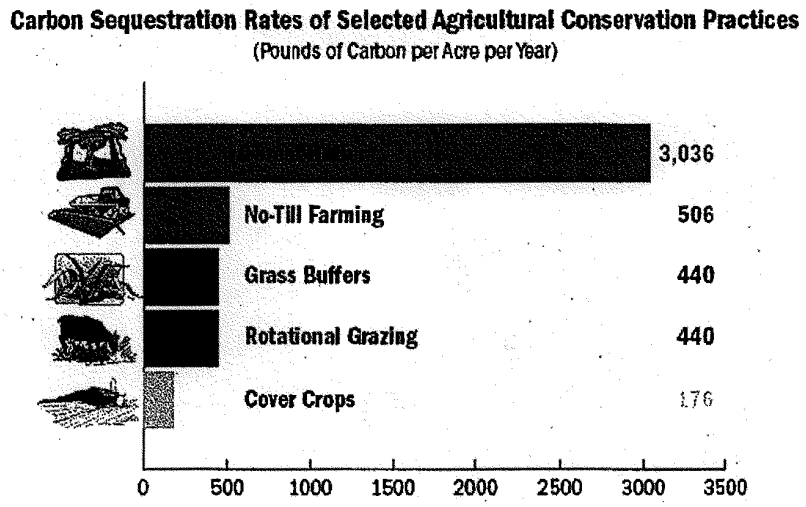
Lastly, in its current degraded state, the Bay itself is a source of greenhouse gases. Under oxygen-deprived conditions, greenhouse gases such as nitrous oxide and methane are formed in the Bay sediments and eventually released into the atmosphere. If we reduce nitrogen pollution to the Bay and decrease the size of the Bay's dead zones, we will reduce the amount of these gases that are produced.

Question 2. Sequestering carbon will have to he part of the solution to curbing greenhouse gas emissions. Can you please tell the Committee about some of the dual benefits we might see through conservation programs in the Farm Bill?

Response. Implementation of agricultural conservation practices, while often overlooked in policy discussions about reducing greenhouse gases, promises to be doubly beneficial for climate change and water quality In the Bay region and beyond.

Carbon sequestration refers to the net removal of carbon dioxide from the atmosphere into long-term or permanent terrestrial 'pools': living (trees or grasses; roots and microbes in the soil), stored in products with long lives such as lumber, or contained as soil carbon. An enormous amount of carbon is stored in the soil and detritus on the soil—the remnants of plants and trees. Agricultural practices can help increase these carbon pools. For example, planting streamside buffers results in carbon sequestered in trees or grasses as well as increasing the amount of carbon in soil. Traditional fanning techniques, such as plowing, reduce soil carbon levels by allowing carbon dioxide to be released into the air, but conservation tillage, where traditional plowing and hoeing are replaced with either no, or shallow, tillage exposes less soil to the air, leading to the retention and increase of soil carbon. Furthermore, these practices can be implemented now, while long-term strategies to mitigate greenhouse gases are developed and implemented.

The chart below highlights the greenhouse gas benefits of some agricultural practices that are supported by Farm Bill conservation programs.



RESPONSES BY WILLIAM C. BAKER TO ADDITIONAL QUESTIONS FROM SENATOR INHOFE

Question. As you know, while progress has been made restoring the Bay, the signatories of the 2000 Agreement are no where near completing most of the goals they outlined for the Bay. Were the goals and the timeframe realistic? In your view, what is the biggest obstacle you are running into?

Response. The Chesapeake 2000 Agreement (signed in June of 2000 by the States of Virginia, Maryland, and Pennsylvania, the federal government, the District of Columbia, and the Chesapeake Bay Commission) set numerous goals and objectives to be achieved by the year 2010. The overarching goal is to achieve clean water. This is defined as removing the Bay and tributary rivers from the Federal Clean Water Act's Impaired Waters List. Ironically, this simply represents compliance with the Federal Clean Water Act of 1972.

While difficult to believe, very little progress has been made toward achieving this goal in spite of a clear knowledge of both the strategy and tactics to meet it. Scientists are consistent in their belief that the Bay states must achieve a 110 million pound annual reduction of nitrogen flowing into the system against a baseline of year 2000 loadings to meet the goal of dean water and a balanced system, resulting in a delisting from the Impaired Waters List.

This goal was and is absolutely achievable, but not without following sound science and putting into place those practices which are proven to be effective. Bottom line, the science, the technology, and even the public support for carrying out this work are available. What has been missing is the political will to get the job done as promised in the Chesapeake 2000 Agreement.

Senator BOXER. Thank you, sir. It was most eloquent.

Senator WARNER. Madam Chairman?

Senator BOXER. Yes, please?

Senator WARNER. I can assure our colleague that that provision is in the bill now, but why don't you look at it. If it needs a little strengthening, let me know.

Mr. BAKER. Thank you, sir.

Senator BOXER. That is a very good offer I would not turn down. [Laughter.]

Senator BOXER. Dr. Christopher Pyke, Member, Chesapeake Bay Program's Scientific and Technical Advisory Committee; Fellow, Virginia Institute of Marine Sciences's Center of Coastal Resources Management. Welcome.

STATEMENT OF CHRISTOPHER R. PYKE, MEMBER, CHESAPEAKE BAY PROGRAM'S SCIENTIFIC AND TECHNICAL ADVISORY COMMITTEE; FELLOW, VIRGINIA INSTITUTE OF MARINE SCIENCE'S CENTER OF COASTAL RESOURCES MANAGEMENT

Mr. PYKE. Thank you, Chairman Boxer, and members of the Committee, thank you for your invitation to discuss the impacts of climate change on the Chesapeake Bay.

In December 2006, the Chesapeake Bay Program asked the staff, the Scientific and Technical Advisory Committee, to review research activities, identify critical knowledge gaps, and make recommendations for next steps in addressing climate change. I am leading STAC's response to this, in collaboration with Dr. Ray Najjar from Penn State University and a team of coauthors.

We conclude that climate change is more than a future threat to the Chesapeake Bay. The Bay Program partners are making long-term, capital-intensive decisions that are expected to yield results for decades into the future. Changes in sea level, temperature, precipitation and other aspects of climate are likely to alter the cost and efficacy of these activities.

Consequently, climate change is an immediate concern for efforts to protect and restore water quality and living resources. Researchers have used historic observations to identify a variety of physical changes in the Bay, including trends in sea level, temperature and precipitation. Modeling studies suggest these trends are likely to continue and potentially accelerate.

While projections of sea level and temperature are relatively well constrained, the greatest uncertainty is associated with precipitation. It is important to develop a better understanding of potential changes in regional precipitation, particularly the implications of

potentially unprecedented combinations of temperature and precipitation.

Environmental monitoring is an essential component of the Bay Program and climate change adds to the already critical need for monitoring and creates new challenges. Bay Program monitoring systems should be designed to detect trends and allow managers to differentiate between changes driven by climate and those associated with other sources of degradation or restoration action.

Climate change also creates new challenges for Chesapeake Bay restoration strategies, including two of the most important, including bay-wide water quality regulation and activities to restore living resources. Calculations used to develop water quality regulation are based on carefully selected historical meteorological observations. However, observations and modeling results make it increasingly clear that historic time series are unlikely to be representative of future conditions. Consequently, it is essential to develop and implement new methods for establishing water quality regulations that explicitly incorporate climate change.

Similar considerations apply to efforts to protect and restore living resources. The Bay Program partners should assess the vulnerability of living resource restoration efforts such as eelgrass and SAV to climate change and require projects to take steps to promote success under changing conditions.

The serious implications of climate change for the Bay Program lead directly to consideration of potential measures to adapt to changing conditions. This is an emerging area of research that has received relatively little attention from the scientific community. Effective adaptation requires linking resource management and monitoring to facilitate changes in practice over time. The Bay Program partners should take action to adapt their management practices to rising sea levels, increasing temperatures, and changing precipitation patterns.

Stepping back, we can identify two general actions that can help the Bay Program partners and other stakeholders address these challenges. First, recognize that climate change is a component of a wide range of decisions associated with water quality regulation, living resource restoration, and other issues. The Bay Program partners can and should immediately require all major resource management decisions to include an assessment with three components. First, identify climatic assumptions. Second, evaluate the potential for climate change to undermine or alter these assumptions. And explicitly consider alternative management options that are more likely to be resilient and adaptive.

The second action is to take a leadership role in addressing climate change across the watershed. The Bay Program partners can and should develop a bay-wide climate action plan that complements State level climate action plans with a specific emphasis on impact and adaptation opportunities relevant to the protection and restoration of the Bay.

In conclusion, it is important to recognize that climate change is an immediate concern for the Bay Program. Fortunately, there are practical steps the Bay Program partners and other stakeholders can take to understand and prepare for changing conditions.

[The prepared statement of Mr. Pyke follows:]

STATEMENT OF CHRISTOPHER R. PYKE, MEMBER, SCIENTIFIC AND TECHNICAL ADVISORY COMMITTEE OF THE CHESAPEAKE BAY PROGRAM; FELLOW, CENTER FOR COASTAL RESOURCES MANAGEMENT, VIRGINIA INSTITUTE OF MARINE SCIENCE; DIRECTOR OF CLIMATE CHANGE SERVICES, CTG ENERGETICS, INC.

INTRODUCTION

Chairman Boxer, ranking member Inhofe and members of the Committee: thank you for your invitation to address the Committee on the important issue of the impacts of global warming on the Chesapeake Bay. I am Christopher R. Pyke, and I currently serve as a member of the Scientific and Technical Advisory Committee for the U.S. Environmental Protection Agency's (EPA) Chesapeake Bay Program (Bay Program). I am also a fellow with the Virginia Institute of Marine Science's Center for Coastal Resources Management, and the Director of Climate Change Services for CTG Energetics, Inc., a green building and sustainable design consultancy. Previously, I served as a physical scientist with the U.S. EPA's Global Change Research Program, and as a co-chair of the U.S. Climate Change Science Program's Human Contributions and Responses Interagency Working Group. I maintain a long-term interest in the implications of climate change for water quality and aquatic ecosystems, and I am actively engaged in a wide range of issues linking land use decisions with climate mitigation, impacts, and adaptation. A brief biography summarizing my professional experience is an attachment to this testimony.

In response to Chairman Boxer's letter of invitation, my testimony provides my views on the impact of global warming on the Chesapeake Bay with particular emphasis on findings from a report I am coordinating on behalf of the Bay Program's Scientific and Technical Advisory Committee (STAC). Although my remarks draw extensively on findings in this forthcoming report, my comments reflect only my own professional opinion and they are not necessarily those of the STAC or any other organization.

SUMMARY

Climate change is more than a future threat to the Chesapeake Bay. The Bay Program partners are making long-term, capital-intensive decisions that are expected to yield results for decades into the future. Changes in sea level, temperature, precipitation, and other aspects of climate are likely to alter the cost and efficacy of many of these activities. In this context, climate change is an immediate concern for efforts to protect and restore water quality and living resources. The Bay Program partners can and should take immediate action to assess the implications of changing climatic conditions for their activities and ensure that restoration strategies will be effective under future conditions.

This outcome can be promoted by immediate action to:

1. Identify and address climatic assumptions associated with important management and policy decisions (e.g., water quality regulation).
2. Evaluate the sensitivity of water quality protection, living resource restoration, and monitoring strategies to climate change and promote the development and implementation of practices that are resilient and adaptive to changing conditions.
3. Develop a comprehensive, Bay-wide Climate Change Action Plan that will serve as a roadmap to prioritize research and management activities and guide the implementation of adaptive responses.

INTRODUCTION TO STAC CLIMATE CHANGE STUDY

The Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) provides guidance to the Bay Program on measures to restore and protect the Chesapeake Bay. STAC accomplishes its mission through technical reports and papers, discussion groups, reviews of Bay Program activities, technical conferences and workshops, and service by STAC members on Bay Program subcommittees and workgroups. STAC reports annually to the Bay Program Executive Council and quarterly to the Implementation Committee. STAC is composed of 38 members drawn from federal and state agencies, universities, research institutions, and private industry.

In December 2006, the Chesapeake Bay Program requested that the STAC evaluate current understanding about the implications of climate change for the Chesapeake Bay, specifically the restoration of water quality and living resources. STAC was asked to review recent and on-going research activities, identify critical knowledge gaps, and make recommendations for next steps in addressing climate change.

STAC's response to this request is being led by Ray Najjar from Pennsylvania State University and myself with assistance from a team of co-authors including

Mary Beth Adams, Denise Breitburg, Carl Hershner, Robert Howarth, Michael Kemp, Margaret Mulholland, David Secor, Kevin Sellner, and Robert Wood.

The forthcoming report will include three sections:

1. A review of scientific research and literature
2. An assessment of gaps in understanding and research priorities
3. Recommendations for next steps

A draft version of the report is currently under internal review by the STAC, and it is scheduled for public release at the end of October 2007. The following comments focus on the second two sections of the report. My testimony draws primarily on this study; however, any specific conclusions or interpretations reflect only my professional opinions.

GAPS IN UNDERSTANDING AND RESEARCH PRIORITIES

The STAC review identified four research themes in recent climate change-related research associated with the Chesapeake Bay:

1. Physical drivers of change
2. Environmental monitoring
3. Impacts on restoration strategies
4. Adaptive responses to climate change

Physical drivers of change

Climate variability and climate change create challenges for the restoration of water quality and living resources in the Chesapeake Bay. Understanding of spatial and temporal dynamics associated with physical drivers is essential to effective responses to these challenges. Researchers have identified a variety of physical changes through analysis of historic observations, including trends in sea level, temperature, and precipitation patterns. Modeling studies suggest that historic trends are likely to continue and potentially accelerate across a wide range of socio-economic scenarios. Projections for sea level and temperature are relatively well constrained. While the greatest uncertainty is associated with one of the most important variables required to understand Chesapeake Bay ecosystems: precipitation. Spatial and temporal changes in precipitation patterns can have far-reaching implications for the Bay ecosystems through impacts on watershed hydrology and biogeochemical processes, particularly under warmer temperature regimes. It is essential to develop a better understanding of potential changes in regional precipitation and the implications of potentially unprecedented combinations of temperature and precipitation.

Environmental monitoring

Environmental monitoring is an essential component of the Chesapeake Bay Program. Computer models and simulations are used to develop environmental policy and regulation. However, the ultimate success (or failure) of these measures is based on real world conditions. Climate change adds to the already critical need for monitoring and creates new challenges. Chesapeake Bay monitoring systems must be designed to detect long-term trends and allow managers to differentiate changes driven by climate from those associated with other sources of degradation (e.g., land use) or restoration action. This information is necessary to evaluate the efficacy of management actions and accurately attribute the causes of improvement or degradation in ecosystem health and water quality. It is essential that the Bay Program evaluate the consequences of climate change for its existing monitoring systems and ensure that sampling designs provide adequate statistical power to detect trends and differentiate sources of improvement or degradation.

Impacts on restoration strategies

Understanding of physical drivers of change and consideration for the effectiveness of environmental monitoring help create the foundation of information needed to consider one of the most critical questions: What are the implications of climate change for the Bay Program's strategies to restore water quality and living resources?

Three of the most important strategies include:

- Bay-wide water quality regulation.
- State tributary strategies designed to achieve the goals of the Chesapeake 2000 agreement.
- Activities to protect and restore living resources, such as submerged aquatic vegetation and oysters.

These strategies are central to the success of the Bay Program, and climate change is likely to jeopardize the validity of key assumptions used in current approaches to developing and implementing these strategies.

For example, calculations used to estimate TMDLs are based on a carefully selected subset of historic meteorological observations. However, observations and modeling results make it increasingly clear that these historic time series are unlikely to be representative of future conditions. It is essential to develop methods for calculating TMDLs that explicitly incorporate information about changing climatic conditions.

State partners have developed implementation plans called tributary strategies. These documents describe the combination of approaches needed to restore Bay water quality. The performance of individual management practices is central to the design of tributary strategies, and our understanding about performance is based on observations under historic climatic conditions. For example, the ability of stormwater detention ponds to capture sediment and remove nutrients varies as a function of precipitation volume and intensity. It is increasingly likely that detention pond designs based on historic precipitation requirements may not meet performance goals under future conditions. Many widely-used water quality Best Management Practices are likely to exhibit similar sensitivities. It is important for the Bay Program partners to assess the consequences of climate change for the effectiveness of management practices.

Similar considerations also apply to efforts to address living resources. Restoration efforts rely on understanding of historic relationships between climatic conditions and ecological processes. However, changes in climate are likely to jeopardize these relationships. For example, planting of submerged aquatic vegetation (SAV) is a major emphasis of the Bay Program; however, SAV is known to be highly sensitive to peak summer temperatures and flow regimes. Climate change is likely to alter both of these variables and alter the likelihood of restoration success. Fortunately, it is possible to identify these climatic assumptions and take action to develop more sustainable restoration plans. For example, experience with coral reef ecosystems suggests that it is possible to identify resilient sites where local conditions offset regional climatic stresses and increase the likelihood of restoration success. This suggests that restoration activities in the Bay may benefit from efforts to identify resilient restoration locations at local and regional scales. The Bay Program partners should assess the vulnerability of living resource restoration efforts to climate change and require projects to take specific steps to increase the likelihood of success under changing conditions.

Adaptive responses

The serious implications of climate change for the Bay Program lead directly to consideration of potential measures to adapt to changing conditions. This is an emerging area of research that has received relatively limited attention from the scientific community.

It is possible to distinguish between resilient and adaptive responses to climate change impacts. Resilient responses help increase capacity of systems to respond to disturbance and accommodate changing conditions. Resilient responses strive to identify opportunities to make decisions more robust to a range of future conditions. Adaptive responses attempt to actively incorporate observations and model projections to anticipate and respond to changing conditions. The goal is to adjust management practices to increase the likelihood of success under future conditions. Unfortunately, adaptive approaches are often constrained by current practices locked by convention or regulation to historic conditions. For example, standard "design storms" are often used to develop stormwater management systems. Observations and modeling results clearly suggest that these design storms are unlikely to be representative of future conditions. Consequently, systems based on these specifications may fail under future conditions. Adaptation requires identifying these climatic assumptions and taking action to anticipate the consequences of changing conditions. This includes creating dynamic linkages between management and monitoring to provide feedback and facilitate changes in practice over time. The Bay Program partners can and should take action to increase the resilience of their activities to uncertain precipitation regimes and begin to adapt their management practices to rising temperatures and sea levels.

NEXT STEPS

Climate change is more than a future threat to the Chesapeake Bay. The Bay Program partners are making long-term, capital-intensive decisions expected to yield results for decades into the future. In this context, climate change is an immediate concern to the restoration of water quality and living resources. The Bay Program partners can and should take immediate action to assess the implications of changing climatic conditions for their activities and ensure that restoration strategies will be effective under future conditions.

Identifying climatic assumptions and sensitivities

The Bay Program partners can and should take immediate action to address these issues through its existing authorities, responsibilities, and resources. The first, and perhaps most important, step is to explicitly recognize that climate change is a component of a wide-range of critical decisions associated with TMDLs, tributary strategies, living resource restoration, and many others. The Bay Program partners can and should immediately require all major resource management decisions to include an assessment that (1) identifies climatic assumptions, (2) evaluates the potential for climatic change to undermine or alter these assumptions, and (3) explicitly considers alternative management options that are more resilient and adaptive.

Climate Change Action Plan

An assessment of climatic assumptions and sensitivities provides immediate opportunities for improvement to internal Bay Program decision making processes. This is necessary but not sufficient to address the scope of the problem. It is equally important for the Bay Program to take a leadership role in addressing climate change across the watershed. One mechanism for achieving this is the development of a broad-based, Bay-wide Climate Change Action Plan. This Plan would build on and complement state-level Climate Action Plans with a specific emphasis on impacts and adaptation opportunities relevant to the protection and restoration of the Chesapeake Bay. The preparation of the plan should begin with the foundation of information provided by the scientific community and quickly broaden to engage the full spectrum of Bay Program partners at Federal, state, and local levels. The plan should include a detailed roadmap for research and management action to help the Bay Program achieve its mission under changing climatic conditions. The Bay Program partners should take immediate action to promote and support the development of a Climate Change Action Plan.

Research coordination and leadership

Improvements to internal decision making and regional coordination are essential components for the Bay Program. A third component involves enhancing the flow of scientific and technical information from the research community to decision makers and managers. Current understanding of the implications of climate change for the Chesapeake Bay is sufficient to raise alarm. For example, there are many reasons to suspect that water quality regulations are highly sensitive to assumptions about climatic conditions. However, the research community cannot yet provide definite recommendations for how to address these concerns.

The current body of knowledge reflects a history where research efforts have generally been broad in scope and, with notable exceptions, lacking in depth and duration. This pattern results from several decades of sporadic funding opportunities, the lack of institutional commitments, and the absence of widely-recognized research priorities. For example, there is no single research group or institution dedicated to climate change research and applications in the Chesapeake Bay.

This situation contrasts with a number of regions with strong, long-standing relationships between climate science, public policy, and ecosystem restoration. For example, the Climate Impacts Group (CIG) at the University of Washington is an award-winning interdisciplinary research group that works to understand natural climate variability and global change to increase the resilience of the Pacific Northwest to fluctuations in climate. The CIG has contributed demonstrably to a foundation of knowledge that supports some of the progressive public policy in the nation with regard to climate change (e.g., King County, Washington's 2007 Climate Plan). The Chesapeake Bay would benefit directly from a similar organization. The Bay Program partners should take the lead in establishing an entity that links climate science, policy, and management throughout the watershed as quickly as possible.

RESPONSES BY CHRISTOPHER R. PYKE TO ADDITIONAL QUESTIONS FROM SENATOR CARDIN

Question. What do you think the essential elements of a science program for the Chesapeake Bay relative to climate change should be?

Response. As I outlined in my testimony, climate change is a cross-cutting challenge to the mission of the EPA's Chesapeake Bay Program and the health of the Chesapeake Bay ecosystem. One of the key messages from my testimony is that climate change needs to be considered as part of many important management decisions. The critical issue is that climate change is not a new issue that "stands apart" from existing concerns. It is a new challenge applicable to many existing responsibilities. Consequently, I strongly believe that a science program for the Chesapeake

Bay should be designed and implemented to provide support for decision makers and managers trying to understand and respond to changing climatic conditions. In other words, a science program for the Chesapeake Bay should be dedicated to the provision of effective decision support.

This should be accomplished through a responsive, collaborative, solutions-oriented applied research program that is guided by the needs of stakeholders, particularly the EPA's Chesapeake Bay partnership. This science program would constitute a climate extension service for the Chesapeake Bay. The success of this kind of activity would be based on successful programs for issues such as soil conservation and wildlife management. In these cases. Federal agencies have a long and successful track record of implementing programs that provide direct benefits to key constituencies and positive return-on-invest for society as a whole. These programs are often highly decentralized, often embedding extension scientists within universities with a mandate to facilitate technology transfer. A similar approach could be devised for the Chesapeake Bay. Ideally, an extension service should strive to create a self-sustaining market for climate change services between private parties. In other words, decision makers would recognize the need to consider climate change in their decision making and hire firms to help with technical analyses. The government can help by providing the foundation of applied research and development needed to establish these markets and, when necessary, rules that protect society's interests by requiring consideration for climate change in decision making (see McGinty 1997 or Babbit 2001).

REFERENCES

Babbit, B. 2001. Evaluating climate change impacts in management planning. Secretarial Order No. 322, Department of the Interior, January 19, 2001.

McGinty, K.A. 1997. Guidance regarding consideration of global climatic change in environmental documents prepared pursuant to the National Environmental Policy Act. Draft memorandum to Heads of Federal Agencies from the Chairman of the Council on Environmental Quality, 9 pages.

Senator BOXER. Thank you, sir.

Dr. Boesch, is that the right way to say it? All right. Dr. Donald Boesch, President, University of Maryland Center for Environmental Science. We welcome you.

STATEMENT OF DONALD F. BOESCH, PRESIDENT, UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE

Mr. BOESCH. Chairman Boxer and members of the Committee, I am very pleased to appear before you today to talk about what we know about the impacts of climate change and global warming, and what we expect to be happening in the Bay in the future.

It is especially a rare honor for me today because I have the privilege of being here with not only my Congressman, but my two Senators and my Governor all at the same time. It is a rare, rare occurrence, as you might understand.

Global climate change is not something in the Chesapeake Bay's future. It is here today. The Bay is warming. Evidence is growing that this is the case. We have two long-term records from the Virginia Institute of Marine Science down in Virginia, and our Chesapeake Biological Lab, that we have now put together. They consistently show about a 2 °F increase in the average temperature of the Bay since about 1960. This follows and is consistent with the patterns we have been seeing in terms of air temperature over much of the Bay watershed, so this is consistent both in observation and argument.

The projections that we can make in the future, of course, in terms of temperature in the Bay must be based upon the kinds of models that we use to project future climate, which predict air temperature changes. If we use those to understand what the impact

on the Bay water may be, we could anticipate over this next century an additional 5 to 9 °F increase in average temperature in the Bay.

This comes, of course, all through the year with warmer summers, as well as warmer winters. As was pointed out, this has substantial effects on the organisms that live in the Bay, influencing things like eelgrass that Mr. Baker mentioned, a very important habitat in the Bay. This plant is near the southern end of its range, and is in serious jeopardy as a result of warming. But also the timing of things that occur in the Bay, the natural cycles in which the food supply for the young striped bass or crabs will be changed and thrown out of kilter, sometimes with unpredictable consequences.

Of course, the other concern we have heard much about from our Governors is the issue of sea level rise. The Bay has much low-lying territory. It has 8,000 miles of shoreline, and we have very extensive areas on the Eastern Shore that are very susceptible. Senator Inhofe mentioned in the opening the fact that the sea level has been rising a long time in the Chesapeake Bay. In fact, that is the case. It rose very dramatically, of course, after the last glacial period of some 300 feet, and flooded the Bay thereby creating the Bay that we now appreciate.

But it has been relatively stable for about 6,000 years. Obviously, since the founding of Jamestown Europeans have been occupants for only a small part of that period. Indeed, that period of time has seen the development of civilization not only here, but in other parts of the world. So as we see these changes that take place, they will affect not only our natural resources, but also our historical resources, as was pointed out by Governor Kaine.

Let's take what we know about the observed rates of sea level rise and the best estimates we have from the models that are used, for example, in the IPCC assessment. One must understand the fact that this region is slowly sinking about one-half foot per century, somewhat more in Hampton Roads, somewhat less in Washington. And then when we add to that the model projections, we could well see a 2- to 4-foot increase of sea level this century over much of the Chesapeake Bay region.

Now, 2 to 4 feet, what does that mean? First of all, sea level rise will probably be at least twice what we have seen in the last century, which was about 1-foot relative to the land. And it could be as much as four times. While this is not the 20-foot inundation that you see in some popular animations, but remember this. Sea level is not going to stabilize in the year 2100. Sea level will not simply rise and then plateau. In fact, because of the lags in the world climate system, it will continue to rise in future centuries. So we have to then plan for a future in which we could see major portions of our historical Bay cities.

As was pointed out by both Dr. Pyke and Mr. Baker, we are already dealing with major challenges in the Bay, and we now have to factor climate change into it. What we need to do, and I think you have heard Governor O'Malley and Governor Kaine now suggest, is to integrate what we are doing to restore the Bay with this new threat of climate change. We must find solutions to address

climate change also to improve the way we are addressing the Bay's problems and vice versa.

In addition, as Dr. Pyke indicated, we really need much more attention from Federal agencies that fund the science and the research that we do to help predict regional scale impacts. A recent study by the National Research Council emphasized that although we have done great as a Nation in leading the world in understanding the climate system on a global scale, we have not emphasized the regional scale. We now need this information to help us plan our future.

So thanks very much for this opportunity.

[The prepared statement of Mr. Boesch follows:]

STATEMENT OF DONALD F. BOESCH, PROFESSOR AND PRESIDENT, UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE, CAMBRIDGE, MD

Chairman Boxer and members of the Committee, I am Donald F. Boesch and am pleased to appear before you today to address what is known about the impacts of global warming on the Chesapeake Bay, what future effects are likely, and what can be done to address the consequences to this magnificent ecosystem, its living resources and the people who live in the Bay region. This is a special honor for me because Maryland's two senators and our Governor are all here today.

By way of background, I am a marine ecologist who has conducted research along our Atlantic and Gulf coasts and in Australia and the East China Sea. Over 25 years of my career have been spent studying the Chesapeake Bay or directing scientists who do. Although not a climate scientist, I have been engaged in several assessments of the possible consequences of climate change on coastal environments and try to keep closely abreast of the emerging climate change literature. Most notably, I served as co-chair of the Coastal Areas and Marine Resources Sector Team for the U.S. National Assessment of Climate Variability and Change[1] and as co-editor of the report Chesapeake Futures: Choices for the 21st Century.[2] And, currently I am serving as chair of the Scientific and Technical Working Group of the Maryland Commission on Climate Change.

A WARMING BAY

Global climate change is not just something in the Chesapeake Bay's future. Evidence is building that it has already resulted in changes in the Bay environment over the last several decades. Based on long-term records from the piers at the Chesapeake's two historic marine laboratories—extending back to 1938 at my Center's Chesapeake Biological Laboratory on Solomons Island, Maryland, and to 1948 at the Virginia Institute of Marine Science at Gloucester Point—it is clear that the Bay has been warming. While annual Bay water temperatures have varied in relation to large-scale climate cycles, such as the North Atlantic Oscillation, there has been a superimposed warming trend of about 1 °C or nearly 2 °F since the 1960s. This is, by the way, consistent with the observed increases in air temperature over much of the Bay region during that same time period.

Because of the close connection of air temperature—the monthly averages rather than the daily extremes—and the temperature of Bay waters, the General Circulation Models used to project future climate conditions as a function of increasing greenhouse gases provide some insight into further changes in temperature in the Bay. Depending on the emission scenarios, these models suggest a 3 to 5 °C (5 to 9 °F) increase in annual mean temperature by the end of this is century.[3] These increases in air temperature may be modulated somewhat as water temperatures respond, but even if we act today to dramatically reduce greenhouse gas emissions

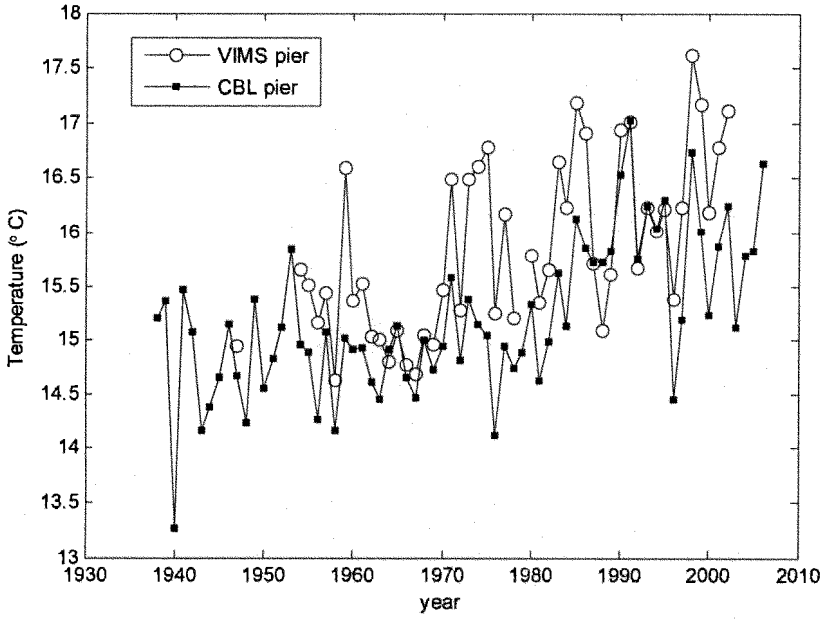
[1] Boesch, D.F., J.C. Field, and D. Scavia. 2000. *The Potential Consequences of Climate Variability and Change on Coastal Areas and Marine Resources.* NOAA Coastal Ocean Program Decision Analysis Series Number #21, National Oceanic and Atmospheric Administration, Silver Spring, MD.

[2] Boesch, D.F. and J. Greer. 2003. *Chesapeake Futures: Choices for the 21st Century.* Chesapeake Research Consortium, Edgewater, MD.

[3] Pyke, C., R. Najjar, M.B. Adams, D. Breitburg, C. Hershner, M. Kemp, R. Howarth, M. Mulholland, K. Sellner, and R. Wood. 2007. *Climate Change Research and the Chesapeake Bay.* Draft. Chesapeake Bay Program Scientific and Technical Advisory Committee, Annapolis, MD.

around the world, the Chesapeake Bay is still very likely to experience significant additional warming.

The much warmer waters during the summer and much milder temperatures during the winter would have substantial consequences for the organisms that live in the Bay and how this ecosystem works. Species that are already stressed by high summer temperatures, such as the eelgrass that provides important habitats in the lower Bay, may be greatly reduced or eliminated. Milder winter temperatures are likely to open the back door to invaders from warm temperate areas around the world who hitchhike into the Bay in ships' ballast waters. With earlier spring warming the critical timing of spawning of species such as striped bass and blue crabs will adjust, potentially out of phase with other processes, such as food production, that are critical to the success of their young.[4]



Mean annual water temperature at the Chesapeake Biological Laboratory (mid-bay) and the Virginia Institute of Marine Science (lower-bay).[5]

INUNDATION

The Chesapeake Bay region is one of the areas of the country most sensitive to the effects of sea-level rise because of its 8,000 miles of shoreline and extensive, low lying areas, particularly on the Eastern Shore.[6] Sea level has been rising in the Bay for a long time, initially as a result of the melting of glaciers at the end of the last ice age. In fact the Bay itself is a series of drowned river valleys, inundated by the rise in the ocean levels of over 300 feet 7,000 to 12,000 years ago. Sea level has been rather stable in recent centuries, however, rising only slowly as a result of the sinking of the land—a slow subsidence of the Earth's crust that had bulged upward

[4] Wood, R.J., D.F. Boesch, and V.S. Kennedy. 2002. Future consequences of climate change for the Chesapeake Bay ecosystem and its fisheries. *American Fisheries Society Symposium* 32:171–184.

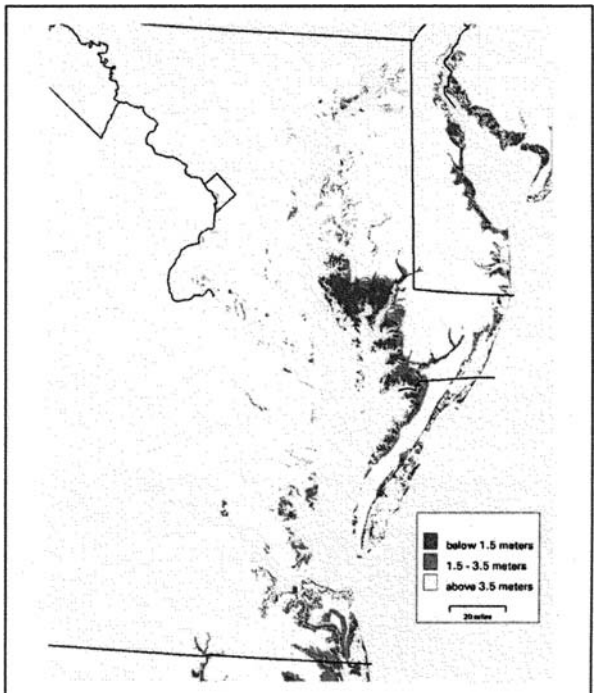
Glick, R., A. Staudt, and D. Inkley. 2007. *The Chesapeake Bay and Global Warming: A Paradise Lost for Hunters, Anglers and Outdoor Enthusiasts?* National Wildlife Federation, Reston, VA.

[5] Austin, H.M. 2002. Decadal oscillations and regime shifts, a characterization of the Chesapeake Bay marine climate. *American Fisheries Society Symposium,* 32:155–170.

Secor, D.H. and R.L. Wingate. In review. A 69 year record of warming in the Chesapeake Bay. *Fisheries.*

[6] Titus, J.G. and C. Richman. 2001. Maps of lands vulnerable to sea level rise: Modeled elevations along the U.S. Atlantic and Gulf coasts. *Climate Research* 18:205–228.

under the weight of glaciers to the north. Still this has been enough to cause the abandonment and, in some cases, disappearance of several islands that had human habitation in the 19th and early 20th centuries.



Land areas estimated to be less than 3.5 meters above mean sea level in 2000.[6]

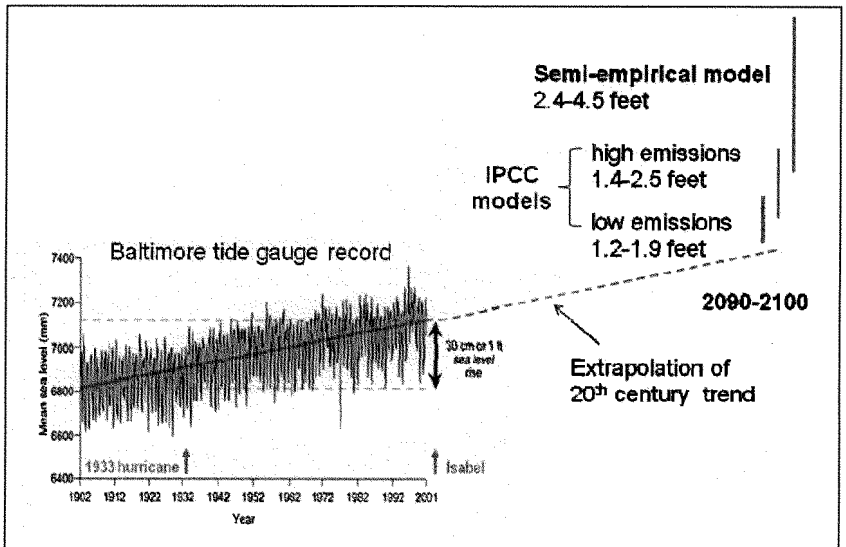
During the 20th century the Bay level rose a little over one foot relative to the land over most areas of the Bay. Accurate tide gauge records at six locations in the Bay showed this relative sea-level rise to range from 2.7 mm per year in Washington, DC to 4.5 mm per year in Hampton Roads, Virginia,[7] with the difference apparently related to differences in subsidence rates. With the rise in the surface of the ocean during the 20th century averaging 1.7 mm per year,[8] subsidence rates vary from 1.0 to 2.9 mm per year and, because this is a slow geological process, are expected to remain constant for the foreseeable future. Satellite altimeter measurements suggest that globally the level of the ocean was rising faster, as much as 3.1 mm per year, during the period 1993 to 2003 than earlier in the century[8]; although this effect is not yet clearly evident in the Chesapeake Bay tide gauge representation of relative sea level because of variation due to winds and other factors.

The Intergovernmental Panel on Climate Change projected average global rise in sea level through the 21st century for different greenhouse gas emission scenarios.[8] If one adds to their rates the average regional subsidence rates for the Chesapeake Bay of 1.8 mm per year, the projections equate to relative sea level rises by the 2090–2100 time period of 0.37 to 0.57 meter (1.2 to 1.8 feet) with aggressive reduction of greenhouse gas emissions and 0.44 to 0.73 meter (1.4 to 2.5 feet) if emissions continue to grow. However, there are several reasons to believe that these estimates

[7] Zervas, C. 2001. *Sea Level Variations of the United States*, 1854–1999. NOAA Technical Report NOS CO–OPS 36. National Oceanic and Atmospheric Administration, Silver Spring, MD.

[8] Solomon, S., D. Qin, and M. Manning. 2007. *Contribution of Working Group I to the Fourth Assessment Report*. Intergovernmental Panel on Climate Change, Geneva.

might be too low. First, as mentioned earlier, satellite evidence indicates that the rise of the global ocean level during 1993–2003 was already much faster than the low emissions estimate. Secondly, the IPCC projections excluded acceleration of the melting of polar ice sheets and evidence is mounting that the melting of the Greenland ice sheet has accelerated. Recently published empirical projections suggest an increase in ocean levels of between 0.5 and 1.3 m,[9] which with regional subsidence would equate to 0.69 to 1.38 meters (2.1 to 4.8 feet) by century's end.



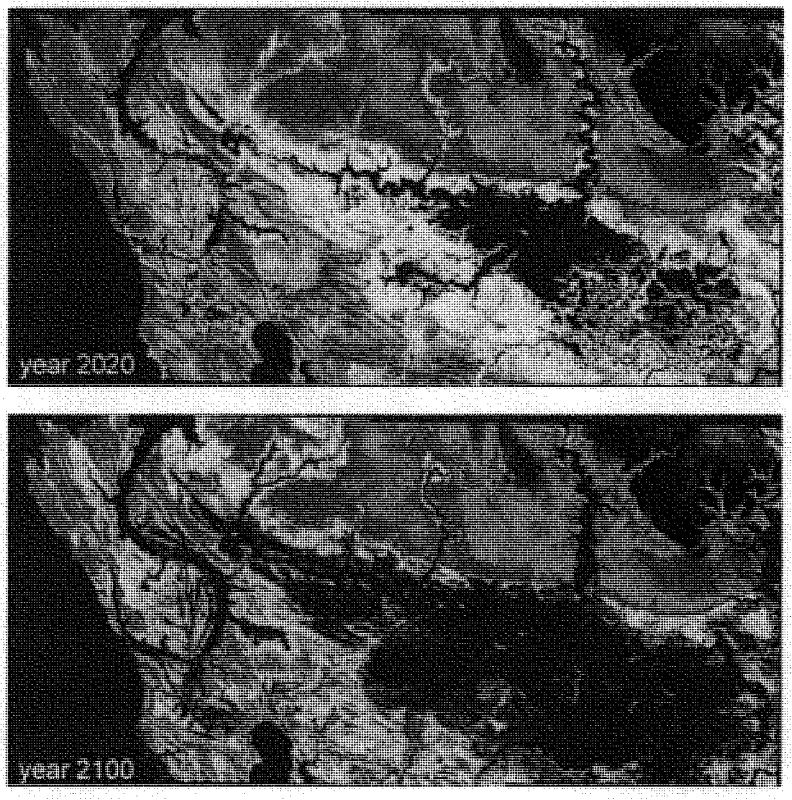
Baltimore tide gauge record for the 20th century with relative sea level rise projections.

While there remains uncertainty, not only as related to behavior of the climate, but also of the level of accumulated greenhouse gases, it appears likely that relative sea level in the Chesapeake Bay will rise twice as much during this century than it did in the previous century and could rise three or more times as much. This rise would probably be measured in several feet, rather than the catastrophic sea level rise of 20 feet or more associated with the complete melting of Greenland as depicted in some popular animations. Still, it is important to keep in mind that sea level would not simply reach a plateau in 2100 but will continue to rise under almost any emission assumption. Furthermore, a rise in Bay water level of just a foot or two will place into jeopardy extensive intertidal wetlands, many of which are already showing deterioration due to inundation,[10] and additional low lying islands. Sea level rise will have profound, but poorly understood effects on the Bay itself. For example, the deepening of the Bay will allow saline ocean water to extend farther up the estuary. Already, this effect seems to be evident in the slight increase in salinity when one factors out the effects of freshwater inflow variations and hydrodynamic models project shifts in salinity significant enough to allow oyster diseases to penetrate deeper into the estuary.[11]

[9] Rahmstorf, S. 2007. A semi-empirical approach to projecting future sea-level rise. *Science* 315:368–370.

[10] Larson, C., I. Clark, G. Gunterspergen, D. Cahoon, V. Caruso, C. Hupp, and T. Yanosky. 2004. *The Blackwater NWR Inundation Model. Rising Sea Level on a Low-lying Coast: Land Use Planning for Wetlands.* U.S. Geological Survey Open File Report 04–1302 http://pubs.usgs.gov/of/2004/1302/index.html

[11] Hilton, T.W., R.G. Najjar, L. Zhong, and M. Li. In review. Is there a signal of sea-level rise in Chesapeake Bay salinity? *Journal of Geophysical Research.*



Changes in tidal marshes at Blackwater National Wildlife Refuge, Maryland, projected under mid-range sea-level rise scenario.[10]

But the effects will be felt in the built environment as well, as roads, utilities, sewerage and drainage systems are threatened with inundation and erosion of developed shorelines and saltwater intrusion into aquifers progress, not only on the Eastern Shore and the imperiled communities on Smith and Tangier Islands, but also in part of the cities of Hampton Roads, Baltimore, Annapolis, Alexandria and the Nation's Capital itself.

These effects will be experienced not just through the slow encroachment of mean sea level but during the extremes, when storm surges build on top of the inexorably slowly rising Bay. For example, in 2003 Hurricane Isabel resulted in storm surges up to 9 feet, typically exceeding the maximum recorded levels of a 1933 hurricane, which had a very similar trajectory and intensity, by about one foot.[12] This is the approximate increase in relative sea level over that 70 year interlude. Add to this the potential for increased frequency and intensity of tropical cyclones as result of warmer ocean waters and there emerges the considerable likelihood of significantly increased vulnerability of the Chesapeake Bay's coastal communities and environments as a result of global climate change.

[12]Boicourt, W.C. 2003. Physical response of Chesapeake Bay to hurricanes moving to the wrong side: Refining the forecasts. In K.G. Sellner and N. Fisher (eds.), *Hurricane Isabel in Perspective.* Chesapeake Research Consortium, Edgewater, MD.

WHAT HAPPENS ON LAND MATTERS

As a large, but shallow estuary with limited exchange with the ocean, the Chesapeake Bay is particularly affected by what drains into it from its 64,000 square mile watershed. Greatly increased inputs of sediments and nitrogen and phosphorus nutrients as a result of land uses, agricultural inputs and atmospheric fallout are the root cause of the deterioration of the Bay during the latter half of the 20th century. And, reducing those nutrient and sediment inputs are the main focus of the Chesapeake Bay restoration program.

Climate change could affect the runoff of nutrients and sediments in a number of ways that interact, making prediction of future conditions somewhat difficult. The wild card is how climate change will affect precipitation and ultimately river runoff. Model projections for precipitation in the Mid-Atlantic region do not have the same level of consistency as those for temperature. However, there is considerable agreement for increased precipitation during the winter and spring.[13] This would likely mean the flushing out of more nutrients through river flow to the Bay during the critical January-May time period, exacerbating water quality problems in the Bay, particularly summertime oxygen depletion of the deep waters of the Bay or the so-called "dead zone."[14] On the other hand, models have less agreement in summer precipitation, with most predicting little or no overall increase but with most rain delivered during intense events that punctuate dry spells. Keeping in mind that warmer temperatures mean more evaporation and plant transpiration this would suggest significantly less river discharge during the summer, which could further allow the salt-water intrusion into the Bay discussed in the context of sea-level rise. Compounding these physical phenomena are the human responses, particularly in agriculture, to changing energy costs, temperature, soil moisture and water availability. These, as well as the still needed pollution abatement practices, will affect the inputs of nutrients in the first place.

RESTORING THE CHESAPEAKE

Substantial public investments have been made and individual actions taken to restore the Chesapeake Bay. Almost $3.7 billion has been spent on that effort between 1995 and 2004[15] and it has been estimated that an additional $15 billion will be required to achieve the water quality objectives of the Chesapeake 2000 Agreement.[16] While some of the changes in the regional climate that are anticipated over the remaining century might actually result in improvements in environmental quality, the tally sheet of reasonable expectations is heavily tilted toward the detrimental in terms of ecosystem recovery. For example, higher winter-spring runoff will require even more efforts to control non-point source pollution in order to receive the same water quality goal for the Bay. The loss of tidal wetlands will reduce their natural cleansing capabilities, and so on.

There are two corollary implications for Bay restoration. First, the impacts of climate change must be factored into restoration goals and actions. No longer should this be put off as too hypothetical, too political or too daunting. Second, mitigating the causes of climate change to avoid dangerous extreme changes should become part of the Bay restoration agenda.

SEEKING COMMON SOLUTIONS

Integrating climate change mitigation and adaptation with Chesapeake Bay restoration requires the search for common solutions. If considered with an open mind, there are opportunities and savings rather than additional costs to be realized. Governor Martin O'Malley has created the Maryland Commission on Climate Change to recommend a Plan of Action for mitigating and adapting to climate change.[17] The Commission has discovered that as practical strategies to reduce the emissions of greenhouse gases are developed in other states there are significant net economic

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[13] Hayhoe, K., C.P. Wake, T.G. Huntington, L. Luo, M.D. Schwartz, J. Sheffield, E. Wood, B. Anderson, J. Bradbury, A. DeGaetano, T.J. Troy, and D. Wolfe. 2007. Past and future changes in climate and hydrological indicators in the US Northeast. *Climate Dynamics* 28:381–407.

[14] Bachelet, D., D.F. Boesch, K.L. Ebi, G.A. Meehl, and R.R. Twilley. 2007. *Regional Impacts of Climate Change in the United States: Four Case Studies*. Pew Center for Global Climate Change, Alexandria, VA.

[15] Government Accountability Office. 2006. *Chesapeake Bay Program: Improved Strategies Needed to Better Guide Restoration Efforts.* GAO–06–614T. Government Accountability Office, Washington, DC.

[16] Chesapeake Bay Watershed Blue Ribbon Finance Panel. 2004. *Saving a National Treasure: Financing the Cleanup of the Chesapeake Bay.* Chesapeake Bay Program, Annapolis, MD.

[17] For information on the activities of the Maryland Commission on Climate Change see http://www.mde.state.md.us/air/mccc/

benefits, although initial investments are usually required to achieve them. Energy conservation and emphasizing transportation options that get many of the single-occupancy vehicles off the roads favor smart growth and reduce impacts to the Bay. At the same time, we need to mitigate if not avoid apparent solutions to the fossil fuel dependence that result in additional degradation of the Bay. In that vein, the rapid increase in growing corn, which has high fertilizer requirements and concomitant nutrient losses, to produce ethanol is particularly troublesome,[18] particularly when, on careful inspection, this seems to produce few if any net reductions in greenhouse gas emissions.

SOUND SCIENTIFIC GUIDANCE

To accomplish this integrated approach to Bay restoration and climate change mitigation and adaptation will require innovative and rigorous science to understand both the synergistic as well as the antagonistic interconnections. While the Chesapeake Bay has a robust scientific community actively engaged in supporting Bay restoration, there is a critical need to build capacity in research, monitoring and assessment related to the consequences of regional climate change. This is largely because the federal science agencies have not invested much in this area. In a recently released review of the U.S. Climate Change Science Program, the National Research Council[19] concluded that:

- Discovery science and understanding of the climate system are proceeding well, but use of that knowledge to support decision making and to manage risks and opportunities of climate change is proceeding slowly.
- Progress in understanding and predicting climate change has improved more at global, continental, and ocean basin scales than at regional and local scales.
- Our understanding of the impact of climate changes on human well-being and vulnerabilities is much less developed than our understanding of the natural climate system.

The Chesapeake Bay Program's Scientific and Technical Advisory Committee[3] has prepared a review and agenda to support the practical understanding of regional climate change that could serve as a blueprint for the needed federal investments. However, we are not in this predicament alone—other regions of the country face similarly daunting challenges in assessing and responding to their climate future.

As I mentioned at the beginning, over seven years ago I contributed to the U.S. National Assessment of Climate Variability and Change, performed under Congressional mandate. Unfortunately, we have lost much the intervening time—a critical period of time when one considers the pace of climate change and the immediacy of decisions that will be required—when informed regional assessments and response strategies could have been developed. I urge Congress to make up for this lost time by authorizing and supporting the regional studies of regional climate dynamics and ecosystem and social responses that are needed to manage our future wisely.

RESPONSES BY DONALD F. BOESCH TO ADDITIONAL QUESTIONS FROM SENATOR CARDIN

Question 1. What do you think the essential elements of a science program for the Chesapeake Bay relative to climate change should be?

Response. As summarized during the hearing by Dr. Christopher Pyke, the Scientific and Technical Advisory Committee of the Chesapeake Bay Program is near completion of a report *Climate Change Research and the Chesapeake Bay* that discusses the status of research in four research themes: physical drivers of change, environmental monitoring, impacts on restoration strategies, and adaptive strategies. The STAC report notes that, in particular, there is a low level of attention to the impacts on restoration strategies and to adaptive strategies. I would agree that a Chesapeake Bay science program relative to climate change should have an essential guiding focus on how climate change will affect our efforts to restore the Bay and on informing the policies and actions for adapting to the inevitable change we will experience in the 21st century. Given that, there are several questions that seem to me to be critically important at the start:

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[18] Chesapeake Bay Commission. 2007. *Biofuels and the Bay: Getting It Right To Benefit Farms, Forests and the Chesapeake Bay.* Chesapeake Bay Commission, Annapolis, MD.

[19] National Research Council. 2007. *Evaluating Progress of the U.S. Climate ChangeScience Program: Methods and Preliminary Results.* National Academies Press, Washington, DC.

(a) How will likely changes in precipitation and evapotranspiration interact with projected land use changes to affect the flow of fresh water, nutrients and sediments into the Chesapeake estuary?

(b) How will likely sea-level rise and the resulting deepening of the Bay affect circulation, the distribution of salinity, groundwater intrusion, stratification, hypoxia, and sedimentation?

(c) How will tidal wetlands and shorelines respond to likely acceleration in sea-level rise and what are the most effective measures that can be taken to avoid or minimize negative impacts to natural environments and human infrastructure?

(d) How will likely increases in temperature and its seasonal timing affect ecologically and economically organisms, potential invasive species and key biogeochemical processes in the Bay?

(e) To what degree will increased CO_2 concentrations in the atmosphere result in acidification of Bay waters and what will be the ecological consequences of such changes?

Question 2. Can you take a moment to explain how you would see an 'adaptive management' program working the Chesapeake region as we deal with the evolving effects of global warming?

Response. More effective application of adaptive management is required for Chesapeake Bay restoration in order to cross-compare model projections on which restoration measures are based with real-world, observed outcomes. This would allow more rigorous evaluation of the effectiveness of restoration efforts, appropriate redirection and redesign, and ultimately much greater efficiencies. This is essentially the point made in the Government Accountability Office's 2005 report *Chesapeake Bay Program: Improved Strategies are Needed to Better Access, Report, and Manage Restoration Progress*. (GAO 06–96). Adaptive management is also useful when changes in environmental and socioeconomic conditions occur and, thus, will be applicable in our efforts to adapt to climate change. For example, as we prepare for likely sea-level rise and river discharges over the planning horizon for Chesapeake Bay restoration, it is prudent to forecast how these changing conditions are likely to affect the attainment of restoration goals and either adjust the goals or measures (e.g. nutrient loading reductions) need to achieve them. Monitoring feeds into this iterative process not only realistic assessment of goal attainment but also information about the changing environment.

What adaptive management cannot do is manage global warming. That is, we cannot monitor sea level, for example, until we observe a substantial acceleration in its rise and then decide to reduce greenhouse gas emissions. The residence times of greenhouse gases in the atmosphere are too long and the responses in Earth's climate systems are too slow for that. Rather, our mitigation strategies must be anticipatory, precautionary and robust.

Question 3. In your experience around the nation, especially in Louisiana and other coastal areas, are they facing the same challenges? Are actions we are discussing important just to the Chesapeake, or are they equally applicable around the country?

Response. Coastal regions are among the most sensitive areas of the world to climate change as they are directly affected by sea-level rise but also are impacted by changes in the frequency and intensity of cyclones and other storms, temperature, and freshwater inflows. No coastal regions on Earth are immune to these effects and some effects, such as in coastal regions of the Arctic that are rapidly eroding due increased wave attack as sea-ice cover is reduced, are already quite dramatic. Coastal regions will vary to some degree in their susceptibility to climate change—compare steep, rocky shorelines to the low-relief coastal environments of Maryland's Eastern Shore of Louisiana, for example. And, coastal ecosystems may be more or less vulnerable to other climate related changes—river flow or temperature, for example. Actions taken to mitigate the increase in greenhouse gases in the atmosphere and thus reduce global warming are of consequence to all coastal regions of the country. However, the steps taken to adapt to inevitable changes will vary considerably depending on the important dynamics, drivers, and vulnerabilities of the region. One might think, for example, that a region like coastal Louisiana with its high rates of land subsidence, already degraded wetlands, and exposure to hurricanes may have few adaptation options. But, that region has the substantial capacity of Mississippi River sediments that could be managed to offset relative sea-level rise that other regions do not.

Question 4. Can you explain to the Committee the relationship you see between the global scientific efforts to understand and deal with global warming and the more regional understanding that is needed for areas like the Chesapeake? What

is a reasonable scale, both geographically and in time, for us to understand and respond to climate change?

Response. Global climate change is being effected by processes in the atmosphere and the ocean that are global in scale, thus scientists have worked to develop global models of geophysical processes that help explain the changes that have been observed and project the changes that we are likely to experience based on current understanding. These models are the basis of the climate change projections made by the Intergovernmental Panel on Climate Change (IPCC) and conclusions about the reduction in emissions needed to stabilize greenhouse gas concentrations and thus the degree of climate change. These models are necessarily of global scope and thus, for practical reasons, do not resolve much detail at the scale of the Chesapeake Bay, its watershed, or the Mid-Atlantic region, for that matter, and consequently only fairly coarse regional projections are provided in the IPCC report. Furthermore, these models are unable to incorporate climatic dynamics that might operate on such region, as opposed to global scales. Furthermore, additional scientific efforts are required to interpret the consequences of the climate changes on regional ecosystems, resources and socioeconomic conditions.

As the National Research Council (NRC) recently pointed out in its report *Evaluating Progress of the U.S. Climate Change Science Program: Methods and Preliminary Results*, the U.S. Climate Change Science Program (CCSP) has done a very good job at keeping the U.S. at the leading edge of discovery science and understanding of the Earth's climate system at global, continental and ocean basin scales, but has been much less effective in predicting climate change at regional and local scales. Furthermore, the NRC found that the CCSP has lagged in advancing the use of that knowledge to support decision making and to manage risks and opportunities of climate change. This is beyond regretable because the congressionally mandated U.S. National Assessment completed in 2001 (*Climate Change Impacts in the United States: The Potential Consequences of Climate Variability and Change*) included very useful regional assessments that provide a solid basis for the science needed to improve regional understanding. In my opinion, the delay by the Federal government over the last six years in accepting the reality of global climate change resulted in avoiding the kinds of scientific investments needed to deal with the consequences of climate change in places where we live. I strongly support the NRC's recommendations that such investments are now urgently needed.

The space and time scales that must be addressed for understanding and response are in an important sense nested. Improving understanding at the regional scale, say on the scale of the Chesapeake Bay and its watershed, is a weak link at this time. However, this understanding will depend on continued development of our skill in making projections on a global scale. Furthermore, understanding and response will also be required on a very local scale, for example judging how sea-level rise and storm surges will affect vulnerability in downtown Baltimore. In the same vein, we need to develop the understanding to make more confident projections over this century, the principal time scale that the IPCC and U.S. National Assessment addressed, but we also need to understand the longer term changes that will occur as a result of actions during this period (e.g. sea level will continue to rise over hundreds of years as a result of the amount of 21st century warming that occurs). And, at the same time we will need to better understand whether anomalies that we see in one or a few years—this year's drought in the southeast or the 2005 hurricane season—are manifestations of climate change or just natural variability.

Senator BOXER. Thank you, Doctor.

At this point, before we hear from Dr. Avery and the rest of the panelists, I am going to hand the gavel over to Senator Cardin because I have an urgent meeting. I am hoping to get back, but if I don't get back, just understand that you have an ally in this California Senator, and I am sure in the other California Senator as well. We share a common set of values based around our water resources, and we face similar challenges. You know that.

I just wanted to ask unanimous consent to place in the record an article that talks about what is happening in Greenland. Senator Inhofe and I have this go-around every time we have one of these hearings. And so I just wanted to make sure in the record goes this article, which points out that over the past 20 years the air temperature in southeast Greenland has risen by 3 °C. That is 6 °F.

As we all know, because the three of us went, you could actually see the ice move if you stay in one place. Every hour you just see the ice move and these magnificent icebergs floating in the Atlantic. It is one of the most awesome sights that I have ever seen. I think I speak for all of us. Knowing that the average age of this ice is 9,000 years, and it is going to disappear in 1 year from the time it breaks off into the Atlantic.

So it is quite an awesome sight, and I recommend that anybody interested in the subject make that trip. It is very much worthwhile. So we will place that in the record, without objection.

[The referenced document follows on page 107.]

Senator BOXER. Again, I want to say to Senator Mikulski, you have added immeasurably to our discussion today, and we are partners in this whole fight against global warming. I am just so honored that you spent your time with us, given all of the requirements on your time.

Senator Cardin, the gavel is yours.

Senator CARDIN [Presiding]. Senator Boxer, we thank you for making this hearing possible. We think it is very important for our Country to understand the practical effects of global warming to the Chesapeake Bay region. You have given us the opportunity to have this hearing. Senator Mikulski and Senator Warner and I all thank you for making that possible.

Senator MIKULSKI. Senator Boxer, I, too, want to echo my support because by focusing on the Chesapeake Bay, we want to bring home the impact of global warming on our own people. Number one, that it has real consequences to people, as you are going to hear about a waterman's family, and particularly to our economy and to our national security, as Senator Warner has indicated.

So we thank you and I thank you for your courtesy in having me. We hope to see our science bill in Commerce, Justice, Science on the floor as part of the October group, and we look forward to your participation to show how important what we do is. Thank you.

Senator BOXER. You can count on my support.

Senator CARDIN. Thank you.

We will now hear from Dennis Avery. He is Senior Fellow, Hudson Institute; Director, Center for Global Food Issues.

STATEMENT OF DENNIS T. AVERY, SENIOR FELLOW, HUDSON INSTITUTE; DIRECTOR, CENTER FOR GLOBAL FOOD ISSUES

Mr. AVERY. Thank you, Senator. I am also the coauthor of a new book entitled "Unstoppable Global Warming: Every 1,500 Years." The book is about the 1,500 year climate cycle that was discovered in 1984 in the Greenland ice cap ice cores by two gentleman named Dansgaard and Oeschger.

Over the last 11,000 years of the planet's history, the 1,500 cycle has dominated our temperatures. The Vostok ice core in the Antarctic indicates nearly 600 of these cycles in the last million years. Each one raised the temperatures in the Bay region by one to 3 °C above the mean for centuries at a time, and then dropped the Bay region temperatures 1 to 3 degrees below the mean for centuries more. The flora and the fauna quietly adapted.

We may not like the stress. We may not like the change, but it has been with us. By the way, Dansgaard and Oeschger shared the

Tyler Prize, the environmental Nobel, in 1996, but today nobody wants to discuss the cycle they found, almost no one.

Thankfully, Senator Mikulski's people have sponsored Tom Cronin of the U.S. Geological Survey, who studied the magnesium and calcium ratios in the Bay sediments. He found temperature shifts of 2 to 4 °C associated with the Little Ice Age, the Medieval Warming, the Dark Ages, the Roman Warming, and presumably would have found them in previous years if the Bay had been alive that long.

Deborah Willard, also of the USGS, found a 1,429 year cycle in the abundance of the Bay's pine trees, associated with winter temperature declines of as much as 2 °C. She also found very long drought periods near the Bay during both the Roman Warming and the Medieval Warming. Again, we may not like these changes, but whatever we do on energy policy is unlikely to trump the sun.

The temperatures of the modern warming are well within the parameters of past natural warming cycles. Our temperatures have increased about .7 degrees since 1850. About five tenths of that occurred before 1940, and thus much before much human-emitted CO_2. Our net warming since 1940 is two-tenths of a degree Celsius, and we have had no warming at all since 1998.

A warming of .1 degrees over 65 years is not much, especially while the atmosphere has been becoming increasingly saturated with atmospheric CO_2. The only place we see radical warming is in the unverified computer models whose early predictions have already proven inaccurate. Nor will sea levels rise much. Higher temperatures evaporate more ocean water, but they also drop more snow to become more ice on Greenland and the Antarctic.

Neils Reeh of the University of Denmark reports a broad consensus among sea level experts that another degree of warming, which would more than double the warming we have had in the last 150 years, would melt enough Greenland ice to raise sea levels three tenths to seven tenths of a millimeter per year. At the same time, it would add enough Antarctic ice to subtract two tenths to seven tenths of a millimeter of sea level per year, leaving us with very little sea level change. The 6 inches per century that we have had in the last 400 or 500 years may be a good guess for the future. We have seen no acceleration since 1850.

No wild species has been found anywhere in the world to have gone extinct because of the higher temperatures. Instead, the tree and plant species, the birds, butterflies, crickets and mammals have been expanding their interlocking ranges, creating more biodiversity per acre than the planet has seen for 500 years. The birds, fish, and mammals of the Chesapeake Region have quietly adapted to the temperature and rainfall changes associated with the cycle. Again, they may not be the changes we would prefer, but I seriously question our ability to stop them.

Fossil pollen shows nine complete reorganizations of North America's trees and plants during the past 14,000 years. That is a cycle of 1,650 years. The number of pine trees varies with the cold. The distribution of the fish species changes with the cold. The one thing I can see that we might impact at this moment is the distribution of corn plants on the Eastern Shore and Western Shore of the Chesapeake Bay. The biofuels program is greatly in-

tensifying corn production and may be intensifying pollution problems in the Bay as a result. That is one thing that we could rein in, even though we can't control the sun.

Thank you very much.

[The prepared statement of Mr. Avery follows:]

STATEMENT OF DENNIS T. AVERY, HUDSON INSTITUTE, DIRECTOR, CENTER FOR GLOBAL FOOD ISSUES

Thank you for the opportunity to present this testimony on a vital public issue.

NO HUMAN IMPACT ON CHESAPEAKE TEMPERATURES?

The first point I must make is that we cannot document any significant current impact from man-made warming on the Chesapeake Bay. Nor are we likely to do so in the future. A number of recent studies have found incontrovertible evidence of a long, moderate natural global climate cycle—which has periodically raised the temperatures of the Chesapeake to higher levels than today, and for extended periods. Quite simply, the Bay has been through higher temperatures before, and will be again. The flora and fauna have also been through these warmer periods, and adapted. That is fortunate, because the natural climate cycle is apparently driven by the sun, and the warmings are unstoppable.

Previous Bay warmings include the Medieval Warming (950–1300), the Roman Warming (200 BC–600 AD), and at least two earlier Holocene Warmings since the last Ice Age 12,000 years ago, that were regarded by paleontologists as warmer than today by several degrees C.[1]

These natural warmings, and the coolings interspersed with them, are called Dansgaard-Oeschger cycles. The cycles are named after their discoverers, Willi Dansgaard of Denmark and Hans Oeschger of Switzerland, who found them when they brought up the world's first long ice cores from the Greenland ice cap in 1983, the Greenland ice cores revealed the 1,500-year cycles for the first time, embedded in 250,000 years of Greenland ice history. (Oxygen isotopes in the ice layers documented the air temperatures that existed when each layer was laid down.)[2] The cycles had been too long, and too moderate, to be discerned by peoples lacking thermometers and written records.

Since the 1980s, the evidence of these cycles has also been found in a 900,000-year Antarctic ice core; in the sediments of at least six oceans and hundreds of lakes; in cave stalagmites on every continent plus New Zealand; in ancient documents in Europe and Asia; in the long-term records of Nile floods; and in archeological remains, which show farms and primitive villages simultaneously moved up the slopes of the Alps and Andes during the warmings, and back down during the coolings.

Fossil pollen shows nine complete reorganizations of North America's trees and plants during the past 14,000 years, in concert with the temperature cycling. In Ontario, this means that beech trees dominated the forests during the Medieval Warming, giving way to more oak trees as the Little Ice Age set in, and finally yielding to more pine trees as the cold intensified. Today, the oak trees are coming back and the beech trees are waiting their next turn.

Both seabed sediments and ice cores show the Dansgaard-Oeschger cycles extending back at least 1 million years, and dominating the earth's temperatures during the last 11,000 years. Incidentally, Dansgaard and Oeschger shared the 1996 Tyler Prize (the "environmental Nobel") with Claude Lorius, leader of the Antarctic team that brought up the Vostok ice core, so the cycle evidence is well-known to the environmental movement.

I have co-written a new book, with climate expert Fred Singer, titled *Unstoppbable Global Warming: Every 1,500 Years.* It cites peer-reviewed studies, authored and co-authored by more than 500 scientists and published in leading scientific journals, which (1) found evidence of the natural cycle, (2) linked it to the sun's variations, or (3) found some other serious flaw in the current global warming alarmism, such as the loss of 1 million wild species or radically increased human deaths. The researchers' scientific specialties range from tree rings, lichens and marine fossils to public health and satellite imagry. There are many more such studies

[1] Nasif Nahle, (2007) "Warmer than current periods in the Holocene epoch," Biology Cabinet, biocab.org/Holocene.html.,.

[2] W. Dansgaard, et al, (1984), "North Atlantic Climatic Oscillations Reveled by Deep Greenland Ice Cores," in Climate Processes and Climate Sensitivity, F.E. Hansen, ed., Geophysical Monograph 29, 28–98, American Geophysical Union, Washington, D.C.

which the book did not cite, and we plan to identify more of them and their authors in the near future.

The Dansgaard-Oeschger cycles are moderate above all. They have typically warmed the earth by 1–2 °C above the long-term average, and then dropped it by 1–2 degrees below the long-term average at the latitude of Washington and the Chesapeake. Arctic temperatures vary more widely, which may or may not stress the polar bears but seems inevitable. The shifts from warm to cool and back are often abrupt, gaining half their total change within a few decades. Near the equator, temperatures change little, but rainfall patterns change sharply, as the tropical rain belts shift north and south by hundreds of miles. This shift in the rain belts has produced mega-droughts in California and very long droughts in the Chesapeake region.

All of the current global warming evidence today is consistent with our Modern Warming being a natural rebound from the Little Ice Age. Our total warming since 1850 is apparently just 0.7 °C. The only place we find dramatically dangerous man-made warming is in the projections of the global computer models—which have been verified with each other, but not with the real world. The models have consistently overestimated the Greenhouse effect, and the UN's Intergovernmental Panel on Climate Change has been slowly and reluctantly reducing its warming forecasts over time.

This moderate climate cycle has raised the Chesapeake's temperatures higher than today as recently as 5,000 years ago. Thus, we can hardly call today's temperatures an "unprecedented" or "unnatural" threat to wild species. Rather, today's temperatures should be regarded as "within the normal range" of the ecosystem, and the responses of the Bay's plants and animals as "normal" adaptations.

RECENT STUDIES OF THE BAY'S LONG-TERM TEMPERATURE HISTORY

In 2003, T.M. Cronin and his research team used the magnesium/calcium ratios in Chesapeake Bay sediment cores to document rapid temperature shifts—2–4 °C within 100 years—in past Chesapeake Bay temperatures.[3] These big shifts occurred:

(a) 150 years ago in 1850 AD
(b) 400 years ago in 1600 AD
(c) 650 years ago in1350 AD
(d) 950 years ago in 1050 AD
(e) 1600 years ago in 400 AD and
(f) 2100 years ago in 100 BC.

The big, sudden temperature changes reflect the Roman Warming, the Dark Ages, the Medieval Warming and the Little Ice Age. Nothing would be more "natural" than the Little Ice Age being followed by another warming.

Cronin and his colleagues noted that the temperatures of the 20th century were 2–3 °C higher than those in the previous 2000 years. However, they did not comment on the Holocene warmings, which other authors have found to be as much as 6 degrees warmer than any of the more recent cycles in the Arctic (with somewhat lesser temperature elevations at lower latitudes).

Debra Willard of the U.S. Geological Survey and a research team in 2005 used pollen from Bay seabed sediments to reconstruct the Bay's temperature history for the past 10,000 years.[4] Her team identified a 1429-year cycle in the abundance of the Bay's pine trees, associated with winter temperature declines of up to 2 °C. The most recent of these cycles correlates with the Little Ice Age. This is consistent with the findings of the Cronin team.

Willard and her authors note that the climate cycle fits well with a similar cycle in the "solar isotopes" (carbon^{14} in trees and beryllium^{10} in ice). The solar isotope cycle, in turn, correlates closely with temperature proxy cycles found in Greenland ice by Dansgaard in 1984 and by Colombia University's Gerard Bond in North Atlantic ice-rafted glacial debris in 2001. All are thus tied to cyclical changes in solar activity.

In 2003, Dr. Willard had used the fossils of tiny marine organisms and the pollen from long-dead trees to construct a record of rainfall in the Chesapeake region for the last 2300 years. The authors found very long dry periods (1) during the Roman Warming, from 200 BC to 300 AD, and (2) during the Medieval Warming, from 800

[3] T.M. Cronin, et al., (2003), "Medieval Warm Period, Little Ice Age and 20th Century temperature variability from Chesapeake Bay," Global and Planetary Change 36: 17–29.

[4] D.A. Willard, et al., (2005), "Impact of millennial-scale Holocene climate variability on eastern North American terrestrial ecosystems: pollen-based climatic reconstruction," *Global and Planetary Change 47*:17–35.

AD to 1200 AD.[5] These droughts were due to the north-south movement of the tropical rain belts as part of the Dansgaard-Oeschger cycling.

The Willard study also found decade-long dry periods during the Little Ice Age, between 1320–1400 and 1525–1650. One of these may have eliminated the "lost" British colony established on North Carolina's Roanoke Island in 1587, during the most extreme growing-season drought in 800 years. The Jamestown colony also had bad weather luck, arriving in 1607, during the driest 7-year period in 770 years.

All of these Chesapeake droughts seemed to reflect much more serious and simultaneous droughts in the Southwestern U.S., including southern California. California's Medieval-Warming droughts have been well-publicized by Scott Stine of California State University.

THE "NEW MATH" OF GLOBAL WARMING

The temperatures of the Modern Warming are well within the parameters of past natural warmings and coolings. The earth has probably warmed about 0.7 °C since 1850, but about 0.5 °C of the warming occurred before 1940, before significant human emissions of CO_2. The pre-1940 warming can, therefore, be credited to the natural cycle.

The net warming since 1940 is a tiny 0.2 degrees, over more than 60 years, during which the atmosphere has become increasingly saturated with CO_2. (After saturation, no more CO_2 be retained in the air around us or have a Greenhouse impact.) Logic would indicate that human emissions can be credited for half of that warming or .1 degree. It is difficult to assign any significant climate change in the Chesapeake to human-emitted fossil fuels.

We have had no additional warming since 1998, though CO_2 levels in the atmosphere have continued to soar. 1934 is still the warmest year of the last century, followed closely by 1998 and 1921, which emphasizes how moderate our warming has been. The solar index has recently turned sharply downward and the temperatures are likely to follow. None of this guarantees that there will be no further warming, but indicates further warming is likely to be moderate.

If human emissions can logically claim only 0.1 degree of warming over 65 years, then the climate models are claiming too high a Greenhouse sensitivity for the atmosphere. There is certainly no published evidence to support the current high numbers. The climate has never warmed anywhere near as much as the IPCC's original forecasts, even with the documented assistance of the current Dansgaard-Oeschger warming.

SPECIES ADAPTATION

It is important to note that no wild species extinction has yet been tied to the rise in earth temperatures since 1850. A claim was made that the Golden Toad, which lived in a Costa Rican cloud forest, went extinct due to higher sea surface temperatures. However, the loss of the Golden Toad has now been blamed on the clearing of the once-forested mountainsides below its cloud forest home, which altered the cloud-forest moisture conditions.

Biologist Chris Thomas of Great Britain has claimed that the world would lose more than a million wild species due to the projected speed and scope of modern global warming, but this claim is literally incredible.

In the first place, the record of past Dansgaard-Oeschger cycles indicates that they are typically abrupt. Yet most of our wild species "body types" date back about 600 million years and are still going strong.

In the second place, the shifts in ecosystems are not likely to be abrupt. Most trees and plants are cold-limited but they are not heat-limited. Stand replacement of trees must await fires or disease outbreaks to clear a path for the invading species to take over. Thus, the current warming is encouraging the vegetation to gradually expand ranges, and the associated fauna have the same opportunity. Study after study, around the world, shows more biodiversity in our forests and wild meadows today than have resided in them for centuries.[6]

Thirdly, Dr. Thomas himself has documented wild species' adaptations to the warming. He has reported on butterflies colonizing "new types of habitat" during the warming, and bush crickets producing more offspring with longer wings, the bet-

[5] Willard, et al., (2003), Late Holocene climate and ecosystem history from Chesapeake Bay sediment cores, USA," The Holocene 13: 201–214.

[6] N.K. Johnson, (1994), "Pioneering and Natural Expansion of Breeding Distributions in Western North American Birds," *Studies in Avian Biology* 15: 24–44. See also E. Pollard et al., (1995), "Population Trends of Common British Butterflies at Monitored Sites," *Journal of Applied ecology* 32: 9–16.

ter to reach new territories.[7] We have already seen dramatic evolutions of wild species, including tolerance for massive quantities of cadmium by mudworms in the Hudson River near a battery factory, and insects quickly developing tolerance for synthetic pesticides.

NOT MUCH SEA LEVEL RISE

Much has been made of the potential of the current warming to melt the Greenland and Antarctic Ice Caps, dramatically raising sea levels. That would certainly impact the Chesapeake. However, it takes 80 times as much heat to melt an ice cube as it does to raise the temperature of the water from that ice cube 1 degree. Recently, we have seen estimates that the Arctic ice has been radically reduced in extent—but the extent of Antarctic ice has simultaneously risen to amazing levels.

Warmer temperatures melt more glacier ice, but they also evaporate more water from the oceans, much of which falls again as snow on the ice caps. More snow becomes more ice, and the Antarctic is currently adding billions of tons of ice per year, mostly on the ultra-cold East Antarctic Ice Sheet. This ice is too cold to melt. It flows downhill virtually in solid blocks, based on the slope of the underlying mountains. It has been flowing at about the same rate for 10,000 years, and that rate has not accelerated during our warming. It would take another 7000 years to get rid of that ice at current rates, according to John Stone of the University of Washington.[8]

Walter Munk of the Scripps Oceanographic Institute reports that glacial melting due to higher 20th-century temperatures can account for only four inches per century of sea level rise[9] Neils Reeh of the University of Denmark reports a "broad consensus" that another 1 degree of warming would increase the melting of Greenland's ice sheet only enough to raise sea levels 0.3 to 0.77 inches—while the additional ice in Antarctica would subtract 0.2 to 0.7 mm per year.[10]

THE EMERGING DANGERS OF GRAIN-BASED ETHANOL

If humans have not significantly changed the Bay's temperatures, they have certainly had other impacts on it. The Willard authors note that European colonization had severe impacts on the watershed and estuary. Forest clearance and farming altered estuarine water quality, with the fossils indicating less dissolved oxygen and increased turbidity. The Willard data also show another drop in the Bay's water quality after 1950, when the fossils indicate water-quality changes associated with increased urbanization, more hypoxia, and more fertilizer use.

A new element of man-made danger now threatens the Bay for the first time, and it is a direct result of our concern about burning fossil fuels. The Federal government has adopted a mandate to produce 35 billion gallons of ethanol per year to help achieve "energy independence" without increasing gasoline use. Unfortunately, America has only corn with which to produce the ethanol, and corn yields only about 50 gallons worth of gasoline per acre per year—against annual gasoline demand of more than 134 billion gallons.

Ethanol's demand for corn has already doubled corn prices, and has bid farming acres away from soybeans, wheat, and cotton. The whole price structure for commodities and farmland has been wrenched upward, causing street riots in Mexico over tortilla prices and China's canceling of further expansion in its ethanol program due to food price inflation. Food prices make up a full one-third of the Chinese cost of living.

The Center's analysis indicates that the current federal ethanol mandate will soon drive corn to $4.50 per bushel, even in the absence of any crop diseases or weather problems in the Corn Belt.

The commodity magazine that follows vegetable oil prices, *Oil World*, recently stated, "It is high time to realize that the world community is approaching a food crisis in 2008 unless usage of agricultural products for biofuels is curbed."

World food demand is rising due to moderate population growth plus rapid income gains. There is no more farmland to bring into production, unless the Sierra Club and Greenpeace are prepared to endorse massive forest-clearing in the American

[7] Chris Thomas, et al. (2001) "Ecological and Evolutionary Processes at Expanding Range Margins," Nature 411: 577–81. Have the species adapted before? They must have. Does the polar bear have adaptation strategies too? That also seems certain. Even though the polar bear is a relatively recent offshoot of the grizzly bear, it goes back some 200,000 years.

[8] J. Stone et al.,(2003), "Holocene Deglaciation of Marie Byrd Land, West Antarctica," Science 299: 99–102

[9] W. Munk, "Ocean Freshening, Sea Level Rising?" Science 300 (2003): 2014–43.

[10] N. Reeh, "Mass Balance of the Greenland Ice Sheet: Can Modern Observations Methods Reduce the Uncertainty?" Geografiska annaler 81A (1999): 735–42.

Midwest to support more corn ethanol. Unfortunately, the U.S. might have to clear 50 million acres of forest for enough corn ethanol to make much of a dent in its gasoline demand.

The President apparently wanted to foster ethanol from non-food sources, but the enzymes to break down the cellulose in switchgrass, corn stalks and wood chips are not yet available, and we do not know when they might be. Corn ethanol is not an adequate substitute for cellulosic ethanol.

I recently toured parts of the Eastern Shore of the Chesapeake Bay. I have never seen such intensive planting of crops. Next to a marina, the owners of a mansion could no longer see the water, because they had planted their front yard to corn! Ethanol plants are being planned for the Eastern Shore that would lock in this intensive cropping pattern, and even intensify it further. The USDA says America's corn ethanol plants will need an extra 1 billion bushels of corn in 2008, and then more and more corn in the years after that.

All to produce high-cost corn ethanol that will not protect the Bay from higher temperatures but will certainly subject it to more soil erosion and potential pollution.

I submit that corn ethanol is merely the first of a whole series of "global warming" decisions that could threaten ecological damage, global food supplies and public health—without "saving the planet."

RESPONSES BY DENNIS T. AVERY TO ADDITIONAL QUESTIONS FROM SENATOR INHOFE

Question 1. I would also like to insert into the record the attached chart. It shows that the Bay's sea surface water temperatures have fluctuated over the last 2000 years. Is this consistent with your understanding of global sea surface temperatures?

Response. Yes, the attached chart represents the Bay's surface water temperatures over the last 2000 years, as found in a study of the Bay's bottom sediments over that period. The study was led by Dr. Thomas Cronin of the U.S. Geological Survey, and published in Global and Planetary Change, Vol. 36, pp. 17–29. The study shows that the Bay's surface temperatures have fluctuated by several degrees Celsius, in a rhythm of about 1,500 years, plus or minus 500 years. The Holocene Warmings 6,000 years ago were particularly strong.

Question 2. What few people outside of academia understand is that those who argue man-made emissions are causing global warming are using computer models to predict the alleged global warming related catastrophes. As noted by Dr. Art Robinson of the Oregon Institute of Science and Medicine "There is no scientific basis upon which to guess that the rise will be less or will be more than this value. Such a long extrapolation over two centuries is likely to be significantly in error—but it is the only extrapolation that can be made with current data. There may be no sea level rise at all. No one knows."

Can you comment on the risks associated with these models and basing future investment decisions on the models' conclusions?

Response. Climate is one of the most complex phenomena we try to understand. The computerized climate models have never been validated with real-world data, and there is no reason to believe that they are giving us accurate forecasts of the earth's climate future. In particular, the IPCC admitted in its 2001 report that the computer models cannot accurately model clouds. Yet Dr. Henrik Svensmark of the Danish Space Research Institute has found evidence that the low, wet clouds, which deflect solar heat back into space, are among our planet's key thermostats. If the computer models cannot model clouds, it is highly unlikely that they can forecast future changes in the earth's temperatures—or in its sea level riser.

Question 3. In Mr. Baker's testimony, he acknowledges that today's climate models are inconclusive about whether more precipitation will fall in the Chesapeake Bay watershed. Mr. Boesch would have us integrate climate change mitigation into our restoration efforts. One of the primary contributors to the Bay's impairment is stormwater runoff. If the models cannot predict future levels of rainfall, do you know how to incorporate those rainfall levels into the mitigation projects?

Response. If the climate models cannot predict future levels of rainfall, then they cannot forecast future stormwater runoff, one of the key Bay variables. The models are particularly bad at attempting to forecast regional climate changes, such as in the Mid-Atlantic States. One model tells us South Dakota will be a future desert, while another model says it will be a swamp. Even if we could believe the models, we would have no guidelines for action.

Senator CARDIN. We will now hear from Dr. David Schnare, Senior Fellow for Energy and the Environment, Thomas Jefferson Institute for Public Policy.

STATEMENT OF DAVID W. SCHNARE, SENIOR FELLOW FOR ENERGY AND THE ENVIRONMENT, THOMAS JEFFERSON INSTITUTE FOR PUBLIC POLICY

Dr. SCHNARE. Thank you, Senator Cardin.

I would also like to thank Senator Mikulski for being here. I have two messages for you, Senator Mikulski. It was some years ago when I had the honor of serving on Appropriations staff when you first came to the committee, and I saw your leadership and I know that your leadership will be needed now on these issues. The one issue that no one seems to be discussing is something known as geo-engineering. It is the mechanism by which humans alter large-scale geophysical processes such as putting sulfates high into the stratosphere to create a sunscreen that would reduce the temperature. This is the identical process that happens when volcanoes erupt and they cause cooling.

Why do I raise this? I raise this because according to Scott Barrett, Professor at Johns Hopkins University in International Policy Studies, he says geo-engineering is inevitable. Why is it inevitable? A report that came out as recently as just this morning suggests that Bangladesh, with a single meter of ocean rise, will lose one third of their landmass and require 25 to 30 million of their people to move. As a result, someone is going to say it is in our interest to reduce global temperatures using this kind of engineering, especially in light of the fact that doing so would cost one one thousandth the cost of relying exclusively on reducing greenhouse gases.

Geo-engineering is not new and it will potentially have an effect on the Bay and rain in this area because, as we have seen in China when they want a sunny day in Beijing, they seed the clouds to the west. This will happen next summer during the Olympics.

Senator MIKULSKI. They seed?

Mr. SCHNARE. Seed with nitrate crystals, which causes it to rain one place and not another. These techniques are already in use to sequester carbon. Significant tests are going on, and there are commercial activities to put iron into the ocean, to grow algae, to sequester carbon. None of this geo-engineering is under a regulatory control or the control of any governmental body.

Yet because it is so inexpensive, because it is inevitable that it will be done because of the economic consequences of not doing it, we need leadership, international leadership and leadership that can begin with this Committee, to examine the significance of geo-engineering with regard to global warming and the means by which we can organize and ensure its use, its safe use, its incremental use, but its recognized high value use.

Senator Mikulski, the research in this area is necessary.

Now, let me turn to the Bay, briefly. If we rely exclusively on reducing greenhouse gases, it is my fear, having served on the staff of EPA's Appropriations subcommittee, that we will rob the purse of all the funds we need to clean up the Bay. The Thomas Jefferson Institute is very proud of its work in bringing together staff from

the Chesapeake Bay Foundation and from the State of Virginia to accelerate the pace with which some of these techniques to reduce nutrient flows into the Bay are used. Never-till farming is an example.

Part and parcel of that, it is critical that there be continued funding, Federal and State funding for these activities. If we let our activities to restore the Bay be sacrificed on the altar of exclusive greenhouse gas reductions, we will have larger dead zones, more fish kills, and a significantly deteriorated quality of the Bay.

It is our view that this Committee should, as part of its approach to dealing with climate change rely as a first response on a thorough examination of geo-engineering and leadership in its use. Absent that, someone else will do it, and the United States will be a bystander watching. That is not in our interest. It is not in the interests of the international community.

Thank you very much.

[The prepared statement of Dr. Schnare follows:]

STATEMENT OF DAVID W. SCHNARE, ESQ. PH.D.[1], THOMAS JEFFERSON INSTITUTE OF PUBLIC POLICY

Good morning Madam Chairman and Members of the Committee. On behalf of the Thomas Jefferson Institute for Public Policy, we appreciate your invitation to attend this Hearing and thank you for the opportunity to participate in a discussion involving two issues on which the Institute has a continuing strong interest—Restoration of the Chesapeake Bay and the implications of alternative responses to global warming and climate change.

The greatest threat to restoration of the Chesapeake Bay comes not from the potential geophysical effects of climate change, but from the potential responses to climate change and, in particular, exclusive reliance on a strategy of reducing greenhouse gases. The scientific community has reached a consensus on this. As Nobel Laureate Paul Crutzen admits, efforts to forestall climate change exclusively through reductions in greenhouse gases is no more than "a pious wish".[2] [3] Public reports show nations have rejected this strategy[4], and without full, massive global cooperation, reliance on greenhouse gas reductions, alone, will fail.

In this light, how do we protect the Bay and otherwise address the potential effects of global warming? In his influential law review article, Jay Michaelson suggests, "We need an alternative to the policy myopia that sees emission reductions as the sole path to climate change abatement," and in particular we need to apply

[1] Dr. Schnare is the Institute's Senior Fellow for Energy and the Environment. His position with the Institute is pro bono. He has been employed by the U.S. Environmental Protection Agency for 30 years and currently serves as a Senior Counsel in the Office of Civil Enforcement prosecuting violations of the nation's Clean Air Act. This testimony reflects the views of the author and does not necessarily reflect the position of the U.S. EPA or the Thomas Jefferson Institute. Dr. Schnare received his doctorate in environmental science and management from the University of North Carolina-Chapel Hill (1978) and his Juris Doctor Cum Laude from the George Mason University School of Law (1999).

[2] P.J. Crutzen, "Albedo Enhancement By Stratospheric Sulfur Injections: A Contribution To Resolve A Policy Dilemma?" Climate Change, September 1, 2006; see: *http://downloads.heartland.org/19632.pdf.*

[3] And see: William B. Mills, "Geoengineering Techniques To Mitigate Climate Change: From Futuristic To Down-To-Earth Approaches", American Geophysical Union, Fall Meeting 2006, abstract #GC51A–0451, "Within the past several years, more and more scientists are questioning whether these techniques can be implemented on a global scale quickly enough to avoid dangerous anthropogenic climate change impacts. Further, some signatories to the Kyoto Protocol have already indicated they will not be able to meet their reductions of emissions by the agreed upon date of 2012, and in fact expect to increase their emissions. An important question becomes: Are there other mitigation techniques that could be used in a supplemental manner to help control anthropogenically-induced climate change should those techniques mentioned above fall short? In fact there are a variety of techniques that are commonly called geo-engineering methods" *http://adsabs.harvard.edu/abs/2006AGUFMGC51A0451M.*

[4] See, e.g., International Herald Tribune at *http://www.iht.com/articles/ap/2007/08/18/asia/AS–GEN–Australia–APEC–Emissions.php*, documenting China's refusal to attempt an 80% reduction, and see, reports on the international agreement to go no further than adopting unenforceabale "aspirational" goals at *http://www.theage.com.au/news/national/move-to-lower-greenhouse-expectations/2007/08/17/1186857774683.html.*

geo-engineering that can prevent global warming and reduce acidification of the oceans.[5] Others agree. Alan Carlin, Senior Economist with the U.S. Environmental Protection Agency argues that geo-engineering is "our best hope of coping with a changing world."[6] It is our best hope because we have firm evidence it will work and because the developing world can afford this approach. As Ken Caldeira, a professor of climate science at Stanford University, explains, reducing greenhouse gases will cost around 2 percent of the gross domestic product while geo-engineering (by putting reflective aerosols into the upper atmosphere) will cost about one-thousandth of that.[7]

Indeed, the IPCC[8] and William D. Nordhaus, Sterling Professor of Economics at Yale University, agree that the price tag for preventing the effects of global warming with geo-engineering is so small as to be considered virtually "costless".[9] More significantly, Professor Scott Barrett, Director of the Johns Hopkins University School of Advanced International Studies argues convincingly that because geo-engineering is the only practical means to mitigate catastrophic climate change, and is a virtually costless means of doing so, use of this technology is inevitable and our task is to ensure we do it in a sensible, incremental and reasoned manner.[10]

Thus, any investments in reducing greenhouse gases that would eat away at our existing investment in protecting and restoring the Bay would be the greatest threat to the Bay.

Restoration of the Bay requires concerted efforts by local, state and federal governments, and funding from each. It also requires a vigorous, market-based application of advanced agricultural practices.[11] Any threat to that funding or the nascent nutrients market is a threat to restoration of the Bay. To date, private and governmental action has done no more than prevent further Bay degradation in the face of growing populations. To achieve full restoration, this local-state-federal-private coalition must expand its current commitments. It will need significant and continuing federal and state funding, as well as an expansion of the means to trade nutrient reduction credits. If it receives this support, we can look forward to restoration of the Bay within the next 20 years. If not, we simply cannot. Thus, the greatest threat to this restoration is not global warming or climate change. Rather, as explained below, barring an earthquake, and in light of the inevitability of geo-engineering, the strategy of relying exclusively on reduction of greenhouse gases stands as the single greatest threat to restoration of the Bay. If we rely exclusively on reduction of greenhouse gases, and prevent use of geo-engineering, advocates for the Bay will get a smaller slice of a smaller pie and the Bay will disappear in the impending ocean rise.

The remainder of this testimony first explains the timescale of climate change and the inevitable use of geo-engineering. Thereafter you will find a discussion of the Chesapeake Bay, its origin and how we are working to preserve and further restore its vitality. Finally, the testimony concludes with a recommendation that this Com-

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[5] Jay Michaelson (JD Yale), "Geoengineering: A Climate Change Manhattan Project" Stanford Environmental Law Journal January, 1998, see, *http://www.metatronics.net/lit/geo2.html#three*

[6] Alan Carlin, "Risky Gamble," Environmental Forum, 24(5): 42–7, (September/October, 2007), see *http://carlineconomics.googlepages.com/CarlinEnvForum.pdf*; and see: "Global Climate Change Control: Is there a Better Strategy than Reducing Greenhouse Gas Emissions?" University of Pennsylvania Law Review, June 2007, see *http://pennumbra.com/issues/articles/155–6/Carlin.pdf*; "Implementation & Utilization of Geoengineering for Global Climate Change Control," Sustainable Development Law and Policy, Winter 2007 see *http://Carlineconomics.googlepages.com/CarlinSustainableDevelopment.pdf*; and "New Research Suggests that Emissions Reductions May Be a Risky and Very Expensive Way to Avoid Dangerous Global Climate Changes," *http://yosemite.epa.gov/EE/epa/eed.nsf/WPNumberNew/2007–07*

[7] Ken Caldeira, Standford University, quoted in the Christian Science Monitor, see, http://www.csmonitor.com/2007/0329/p13s02-sten.htm.

[8] IPCC Climate Change 2001: Report of Working Group III: Mitigation "It is unclear whether the cost of these novel scattering systems would be less than that of the older proposals, as is claimed by Teller et al. (1997), because although the system mass would be less, the scatterers may be much more costly to fabricate. However, it is unlikely that cost would play an important role in the decision to deploy such a system. Even if we accept the higher cost estimates of the NAS (1992) study, the cost may be very small compared to the cost of other mitigation options" (citing to Schelling, 1996). See, *http://www.grida.no/climate/ipcc*_tar/wg3/176.htm

[9] William D. Nordhaus, "The Challenge of Global Warming: Economic Models and Environmental Policy", Yale University, July 24, 2007; see: *http://nordhaus.econ.yale.edu/dice*_mss_072407_all.pdf.

[10] Scott Barrett, "The Incredible Economics Of Geoengineering" Johns Hopkins University School of Advanced International Studies, 18 March 2007, (in press, Environmental and Resource Economics).

[11] See, David W. Schnare, "Only a Market Can Clean Up the Bay", PERC Reports (June 2007) *http://www.perc.org/perc.php?subsection=5&id=887*.

mittee take a leadership role in building a two-pronged attack on climate change—one relying on geo-engineering as a first response and cost-effective greenhouse gas reduction as a final response.

CLIMATE CHANGE AND GEO-ENGINEERING

As the Committee knows, the international policy community defines the term climate change as human-caused changes in climate and geophysical processes. The current assumption is that, if we do nothing, greenhouse gases will cause further increases in global temperature that, in turn, will cause no less than seven irreversible geophysical events. Those events, in turn, will cause large increases in ocean levels and other undesirable outcomes.

The seven (preventable) irreversible events reach their first "tipping point" with melting of the Greenland ice sheet, an event that commences with a 1.2° to 2°C rise in global temperature and which, according to the IPCC (2007) may have already, albeit slowly begun. We must keep in mind, however, that complete melting of the ice sheet would cause a 7 meter ocean rise only after some 300 to 1,000 years. This long melting timescale assumes CO_2 rises to nearly three times the current level (four times the pre-industrial level) and stays that high for a millennium. Notably, science marches on, and in February of this year, a report on the assumptions underlying these estimates indicate that the IPCC estimate of the rate of sea-level rise is 29 percent higher than the actual value, while another analysis suggests the timescale is smaller than the IPCC estimate.[12] Thus, Greenland ice sheet melting may be more than 300 years off.[13] The other six events do not reach their tipping points until global temperatures increase by about 3° to 6°C and include: loss of the Amazon rainforest, melting of the West Antarctic Ice Sheet, loss of boreal forests, massive positive and negative rain and heat effects in the Sahara and Sahel, stoppage of the Atlantic ocean circulatory system, and increases in ENSO amplification, leading to large shifts in climate over important agricultural lands worldwide.[14] The only event necessary to destroy the Bay is complete melting of the Greenland ice sheet.

If permitted to occur, the land surrounding the Bay would eventually flood and the Bay itself would become no more than a part of the continental shelf. Under this assumption, as the watershed slowly submerges, the Bay environs would lose habitat, ecological integrity and commercial and recreational value. Notably, as part of a new coast line, we would also gain habitat, evolve a new ecological system and gain new commercial and recreational opportunities. According to the IPCC (2007), the loss of existing shoreline would begin very slowly and inundation would not occur for 300 to 1,000 years. As discussed below, natural processes may cause a similar degree of flooding at any time and are more likely to occur than the predicted climate change.

Increasing greenhouse gas levels may also cause a second undesirable effect, ocean acidification. Modeling of climate change acidification effects has not focused on the Bay or similar estuarial waters, particularly with regard to the types of organisms prevalent in or sought to be resurrected in the Bay and its freshwater tributaries. Geo-engineering can also address this problem, as seen in the liming activities long used in Scandinavia to prevent acidification of their fragile lakes.

We have every reason to believe that neither of these climate change-related geophysical effects will ever harm the Bay because, as Professor Barrett explains, some party will apply geo-engineering techniques that will prevent the warming and protect the commercial activities in the Bay. What, then, is geo-engineering?

GEO-ENGINEERING—THE INEVITABLE RESPONSE

In general, geo-engineering is the deliberate modification of large scale geophysical processes and, in the context of this testimony, that means by processes other than by limiting the atmospheric concentration of greenhouse gases. The first of the two most common examples cited is placement of reflective aerosols into the upper atmosphere in order to reflect incoming sunlight and thus reduce global tem-

[12] G. Wöppelmann, et al., "Geocentric sea-level trend estimates from GPS analyses at relevant tide gauges world-wide", Global and Planetary Change 57 (2007) 396–4. But note, while not a specialist in glaciers and ice sheets, Jim Hansen (NASA) argues that by 2100 we could expect a five meter rise in ocean levels due to melting of the Greenland ice sheet. As argued by Barrett, the timescale estimate is irrelevant as a mere one foot increase in sea level will occasion the inevitable use of geo-engineering.

[13] G. Wöppelmann, et al., "Geocentric sea-level trend estimates from GPS analyses at relevant tide gauges world-wide", Global and Planetary Change 57 (2007) 396–4.

[14] Timothy M. Lenton, "Tipping Points or Gradual Climate Change?", (*t.lenton@uea.ac.uk*) School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK

perature. The second is injecting iron into parts of the ocean in order to speed the growth of phytoplankton and thus sequester carbon. Similar techniques can be used to inject lime into the ocean and reduce near-coast water acidity, and thereby protect coral reefs and shellfish.

You might think of geo-engineering as a human effort to replicate natural processes such as volcanic eruptions that inject large quantities of sulfates into the air and thereby shield the planet from sunlight. The eruption of Mount Pinatubo in the Philippines in 1991 injected a significant amount of sulfur dioxide into the stratosphere, lowering the Earth's surface temperature by about 0.5 °C the year following the eruption.[15]. Indeed, there have been many examples of intended and unintended geo-engineering, including some that have exacerbated warming. For example, when coal is burned, sulfate particles are thrown into the troposphere, thus limiting the amount that global temperatures rise due to carbon dioxide, something also produced when burning coal. But, the U.S. EPA has established regulations to limit the emission of sulfates into the atmosphere and by reducing emissions of these sulfate particles, U.S. EPA has inadvertently exacerbated global warming. In another example, jet aircraft routinely emit sun-blocking exhaust into the atmosphere.[16]

Scientists have been studying geo-engineering solutions for a considerable time. As early as 1996, the American Association for the Advancement of Science sponsored a symposium on the subject,[17] and recent contributions are reaching substantial numbers.[18] As discussed in the geo-engineering literature generally, because these techniques mimic natural phenomena, we know more about how quickly and well they work than we do about the efficacy of attempting to reduce greenhouse gases. We have measured the effects of the natural processes and can state with considerable certainty, bordering of complete certainty, that they will produce the result sought. Although the effects of greenhouse gas reduction would occur over a period of no less than decades and more likely centuries, the effects of geo-engineering can (and will) be manifest in a matter of weeks after application.[19]

The extremely low cost of geo-engineering allows many like Barrett to describe these techniques as economically "incredible." Table 1 shows that geo-engineering is not merely 200 to 2000 times less expensive, it prevents more damage than exclusive reliance on carbon control. Further, consider a risk not included in the $17 Billion worth of residual global warming damages shown in Table 1—the $10 Billion a year cost to the United States from UV-caused cancer that would be avoided using geo-engineering.[20] In practical terms, the benefits to the United States, alone, and for UV-related cancer, alone, justify using geo-engineering—a gift to the world that would prevent some $5.2 Trillion in global warming-caused damages.[21]

Table 1

	Total Present Value Abatement Cost (2005 $Billions)	Residual (unprevented) Global Warming-Related Damages (2005 $Billions)
Exclusive Reliance on CO_2 Emissions Reductions:		
(Nordhaus "optimal", 2007)	$2,200	$17,000
Aerosol geo-engineering:		
(Nordhaus, 1994)	$10	0
(Teller et al., 2003)	$1.2	

[15] Crutzen, P.J. (2006). "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?" Climatic Change 77: 211–219. *http://downloads.heartland.org/19632.pdf.*

[16] Travis, D.J., A.M. Carleton, and R.G. Lauritsen (2002). "Contrails Reduce Daily Temperature Range." Nature 418: 601

[17] Six papers delivered at the AAAS symposium appear in Clim. Change, 33(3), July 1996, edited by G. Marland. They cover scientific, legal, technical, political and ethical questions. See, *http://www.gcrio.org/gccd/gcc-digest/1996/d96aug2.htm.*

[18] See, for example, the citations in Crutzen (2006), Barrett (2007) and Carlin (2007b), cited in supra notes 14, 10 & 6, respectively.

[19] Wigley, T.M.L.. "A Combined Mitigation/Geoengineering Approach to Climate Stabilization." Science 314: 452–454. (2006)

[20] Teller, E., Hyde, R., Ishikawa, M., Nuckolls, J., and Wood, L. "Active stabilization of climate: inexpensive, low risk, near-term options for preventing global warming and ice ages via technologically varied solar radiative forcing," Lawrence Livermore National Library, 30 November, 2003.

[21] Nordhaus (2007) *http://nordhaus.econ.yale.edu/dice*__mss__072407__all.pdf.

Notably, geo-engineering has gone commercial. Planktos, Inc., for example, is a for-profit ecorestoration company based in San Francisco with offices in the European Union and British Columbia. Their primary focus is to restore damaged habitats in the ocean and on land. They inject iron into iron-deficient waters to induce large blooms of plankton. This helps sequester carbon and Planktos sells carbon sequestration credits on the various carbon markets.[22] One must ask, if private geo-engineering to sequester carbon is already in play, can private geo-engineering to reduce global temperatures be far behind? Considering the potential harm from global warming, the potential regulatory costs associated with a greenhouse gas-based strategy and the relatively low cost of launching sunscreens, there is good reason to believe the inevitable use of geo-engineering to limit global temperature risk could occur in the private sector. This is a troubling concern many have discussed and on which this testimony touches in its final section.

THE CHESAPEAKE BAY AND ITS RESTORATION

The Chesapeake Bay is a relatively recent geo-physical development. It exists because of a meteor impact occurring 35 million years ago. The impact fractured the earth's mantle and created a depression that forced rivers to reverse their flows and cut paths into what is now the Bay estuary. But the Bay formed long thereafter. As late as 18,000 years ago, the bay region was dry land; the last great ice sheet was at its maximum over North America, and sea level was about 200 meters lower than today. This sea level exposed the area that now is the bay bottom and the continental shelf. With sea level this low, the major east coast rivers had to cut narrow valleys across the region all the way to the shelf's edge. About 10,000 years ago, however, the ice sheets began to melt rapidly, causing sea level to rise and flood the shelf and the coastal river valleys. The flooded valleys became the Chesapeake Bay and the rivers of the Chesapeake region converged at a location directly over the buried crater.[23]

This ancient meteor created many faults that now cut through the sedimentary beds below the site of the impact, many of which lay no more than 10 meters below the bay floor. These faults are zones of crustal weakness and have the potential to suddenly collapse and thus flood large portions of land surrounding the Bay. In other words, we now confront natural and potentially cataclysmic coastal flooding we cannot prevent and in a timeframe we cannot predict.

Rather than permit this inevitability to limit our economic interests in the Bay, we instead accept the risk and seek to preserve this ecosystem for as long as nature allows. On the geological clock, our interests reflect mere ticks of the second hand.

We measure the timescale of Bay degradation and restoration in decades, not centuries or millennia. A mere 70 years ago, the Bay was the largest commercial fishing waters in the U.S. If restored, the Bay could produce $3 billion in commercial fishery revenues per year. It now produces less than $100 million. Overall, some suggest the fishing and recreational value of a bay at full ecological competence (assuming the ecology of the past) at more than a trillion dollars.[24] Virginia, Maryland, Pennsylvania, the District of Columbia, the U.S. Environmental Protection Agency, and others, began their efforts to recover the ecological wealth of the Bay only 20 years ago. They have succeeded in preventing significant further deterioration despite large increases in population density and growth over the intervening years.

An entire array of local, state and federal regulatory programs now protect the Bay as an ecological, recreational and commercial resource. The size of the annual revenues generated within the private marketplace for Bay related activities from mere shore-side residence to recreational swimming and sailing and to commercial activities like fishing, all testify to our success in maintaining, and to some degree improving the quality of the Bay. Nevertheless, problems persist. The Bay suffers from two threats that the current regulatory programs have not resolved: the discharge of sediments and nutrients into the waters of the Bay's watershed. The sediments bury the life on the bottoms of rivers, deltas, and shorelines. These include the extremely important breeding grounds for mollusks and fish. As the name implies, nutrients, specifically nitrogen and phosphorus, provide essential "food" to algae and other small life forms that constitute the bottom of the food chain in the bay. Too many nutrients, however, and the algae can consume too much oxygen, thus forcing the top of the food chain (the fish) to other waters, and causing mollusks and fish hatchlings to fail to thrive and eventually die. Restoration will re-

[22] See, *http://www.planktos.com/About/About.html*

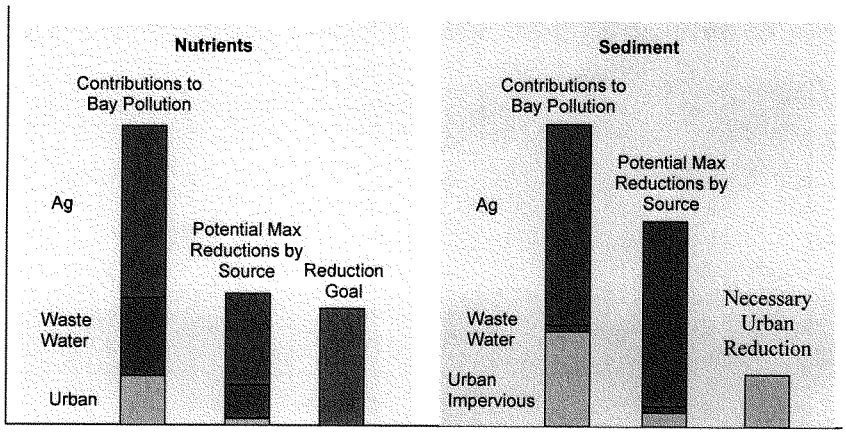
[23] C. Wylie Poag, U.S. Geological Survey, "The Chesapeake Bay Bolide Impact: A New View of Coastal Plain Evolution", July, 1, 1998. See: *http://marine.usgs.gov/fact-sheets/fs49–98/*.

[24] Rebecca Hanmer, U.S. Environmental Protection Agency, "Chesapeake's value worth more than the sum of its parts", see *http://www.bayjournal.com/article.cfm?article=2395*.

quire reductions in both sediments and nutrients by two critical sectors on the watershed, municipalities and the agricultural community.

Figure 1, below, shows the significant sources of the threats to the Bay and each source's potential to reduce discharges. As these charts show, all sources will have to participate in reducing nutrient loadings into the Bay. In some cases, municipalities simply will not be able to do their share, in part because they simply will not have the funds needed to build advanced water treatment facilities. If response to climate change empties the state and federal environmental purse, as would happen with current legislative proposals, then we will not only lose the battle to restore the Bay but will lose ground due to continuing population growth. Even with current funding levels, municipalities will not have the capacity to do their share. Fortunately, in Virginia, the state legislature has authorized a state nutrients bank that allows municipalities to pay others to reduce nutrients when they can not. In the main, those "others" are our agricultural community.

Figure 1



Reduction of nutrients from agricultural sources takes several forms, but controls on concentrated animal feeding operations (CAFOs) and "never-till" crop management seems the most promising. By leaving all but the harvestable grain in the field, by not tilling the field and by planting cover crops to hold nutrients and soil in place over the winter, this cropping technique has reduced nutrient and sediment runoff from those croplands by over 95 percent.[25] Ten years ago farmers used these conservation tillage practices in only rare occasions. In Virginia today, farmers have nearly 15 percent of small grains and corn cropland in never-till management. To expand this number significantly will require a more robust nutrient market, increased technical agricultural assistance and further funding of transition to conservation tillage. Like municipal wastewater treatment, we will succeed in solving this problem only if response to climate change does not empty the state and federal environmental purse.

With regard to sediment, again the agricultural community has the tools to resolve much of the problem. Conservation tillage holds sediments in the field, reducing sediment discharge by over 95%. Indeed, the nutrients adhere to the sediments and in particular the carbonaceous elements within the soil. Further, conservation tillage sequesters carbon in the soil. And, the farming community has already recognized the potential to reap carbon sequestration dollars through never-till farming.[26]

At present, Iowa's Farm Bureau is currently providing services to allow farmers to participate in the carbon sequestration market.[27] Notably, for every ten pounds

[25] See: *http://www.charlescity.org/2rivers.php*. There is a wealth of technical science on no-till and never-till cropping, as a browse through an internet search will access.

[26] See, *http://www.ppionline.org/ppi—ci.cfm?knlgAreaID=116&subsecID=900039&contentID=252026*.

[27] See, *http://www.iowafarmbureau.com/special/carbon/default.aspx*.

of carbon sequestered through never-till practices, a pound of nitrogen (and an equivalent weight of phosphorus) is also sequestered in the soil.[28]

In light of the financial interest the farming community has in carbon sequestration and the potential for large scale positive effects of conservation tillage on the water quality of the Bay, we believe Bay restoration should be considered an element of climate change mitigation, but recognize this opportunity will disappear if funding for both municipal and agricultural Bay restoration efforts evaporate.

We further suggest that the timescale of Bay restoration stands in stark contrast to the timescale of climate change and the timescale of a response to climate change that relies exclusively on reduction of greenhouse gases.

We recommend something else.

GLOBAL LEADERSHIP ON GEO-ENGINEERING—AN UNMET NATIONAL DUTY

In light of the inevitable use of geo-engineering to prevent further global warming, this Committee may be well advised to follow Professor Sunstein's admonition to avoid the twin dangers of over-reaction and apathy.[29] So too would groups that have decided to bypass Congress and attempt to convince State governments to commit to policies relying exclusively on regulatory reduction of greenhouse gases.[30] Sunstein recommends that Congress try to ameliorate, if not avoid, future catastrophes, by looking at the widest possible solution set, by rejecting preconceived notions and emotion-based argument, thus retaining our sanity as well as scarce financial resources that can be devoted to more constructive ends.

Sunstein makes an important point on the need to remember we have goals other than carbon reduction. In this hearing you cannot fail to recognize that commitment to a remedy based exclusively on reduction of greenhouse gases would sacrifice our current commitment to restoration of the Bay. Having served on the staff of the Senate appropriation committee, I thoroughly understand the level of competition for federal dollars. I know you do too. As you consider how to respond to global warming, I ask that you keep in mind what programs you will cut in order to pay for what you propose. And keep in mind that use of geo-engineering will pay for itself, while exclusive reliance on greenhouse reduction will not only fail to pay for itself, it will fail to prevent global warming.

In light of Professor Sunstein's admonition, and the economic and fiscal realities of global warming, geo-engineering and alternatives thereto, the most sensible approach would be a mixed strategy of geo-engineering to prevent further global warming and the effects of ocean acidification over the next century or two and vigorously developing a transition from carbon-based energy, to include research on scrubbing greenhouse gases from the atmosphere. Lacking this two-pronged attack, current legislative proposals must be considered what Sunstein calls "over-reaction" or panic.

We can make no more eloquent argument than that of Professor Barrett regarding what next this nation should do with regard to climate change, so this testimony ends by quoting his recommendation:

> Mitigating, forestalling, or averting global climate change is a global public good. Supplying it by means of reducing emissions is vulnerable to free riding. Too few countries are likely to participate in such an effort, those that do participate are likely to reduce their emissions by too little, and even their efforts may be overwhelmed by trade leakage (Barrett 2005). Geoengineering presents a very different set of incentives. A single country can deploy a geoengineering project on its own—and the economics of geoengineering are so attractive that it seems likely that a country, or perhaps a small group of countries, may want

[28] Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation: A Global Data Analysis, see, *http://cdiac.ornl.gov/programs/CSEQ/terrestrial/westpost2002/westpost2002.pdf*.

[29] Cass R. Sunstein, Karl N. Llewellyn Distinguished Service Professor of Jurisprudence, University of Chicago, Worst-Case Scenarios", Harvard University Press (2007).

[30] The worst example of this narrow-minded approach was recently used in North Carolina and is on the hunt in many other states. One group (Center for Climate Strategies), funded by foundations committed to raising alarm about global warming, has used non-transparent, highly subjective and openly coercive methods to exclude discussions on alternatives to their preferred carbon-reduction strategy. Notably, this group has failed to provide your testifier the basis for their analysis or the assumptions they used in their analysis. They have failed to consider a policy of limiting action only to those efforts likely to reduce global warming. And, they refuse to estimate the effects their proposals on global warming. Groups such as CCS offer a false promise in light of the international rejection of greenhouse gas proposals required to prevent significant warming. See: *http://www.carolinajournal.com/exclusives/display—exclusive.html?id=4087*

to try to do so at some point in the future, especially should the worst fears about climate change ever unfold.

The challenge posed by geoengineering is not how to get countries to do it. It is to address the fundamental question of who should decide whether and how geoengineering should be attempted—a problem of governance (Barrett 2007). Failure to acknowledge the possibility of geoengineering may or may not spur countries to reduce their emissions, but it will mean that countries will be unrestrained should the day come when they would want to experiment with this technology. This, to my mind, is the greater danger.

Madam Chairman, as this Committee demonstrates leadership in protecting the Chesapeake Bay while meeting its duty to help prevent catastrophic climate change, it should champion sensible, incremental, international geo-engineering, in addition to reasoned, cost-effective efforts to limit greenhouse gases.

Because the Barrett and Carlin messages are of such paramount importance, I have attached hereto copies of their seminal papers. [The referenced document follows on page 109.]

RESPONSES BY DAVID W. SCHNARE, ESQ. PH.D., TO ADDITIONAL QUESTIONS FROM SENATOR INHOFE

Question 1. Can you expand on your testimony regarding the natural processes that may cause the flooding of the Chesapeake Bay and why you think that is more likely to occur than flooding from climate change?

Response. The phrase "flooding of the Chesapeake Bay" has been used in an ambiguous manner. The concern about "flooding" reflects two different phenomena—ocean level rise and land subsidence. Thus, the question asks whether ocean level rise, presumably from global warming, is less or more likely to happen than land subsidence. Under either condition, coastal lands will be submerged—surely a considerable human and environmental loss. The likelihood of this occurring due to global warming and related ocean rise, however, is relatively small, considering our ability to prevent such warming, either through heroic reductions in CO_2 or through solar radiation management, a form of geo-engineering. Director of Johns Hopkins International Programs and graduate of the London School of Economics in Natural Resource Economics, Professor Scott Barrett explains that the cost of solar radiation management is so small, a mere billion dollars a year compared with tens of trillions per year for CO_2 reduction, that the use of this geo-engineering is inevitable. If the United States or some international body does not use the technology, some nation at great risk from flooding will. Thus, the likelihood of flooding of Bay tidal lands due to global warming is very small.

Conversely, the likelihood of land subsidence from geological faults is not merely high, it is common. The lands around the Bay have seen twice the flooding as the rest of the world specifically because of this subsidence. Indeed, the area is overdue for an earthquake—one which will cause significant subsidence around the crater that created the lower portions of the Bay.

Thus, flooding due to subsidence is certain to occur while the likelihood of flooding from global warming is unlikely.

Question 2. Let's assume that greenhouse gases will cause temperatures to rise, why will current legislative and environmental organizations' proposal fail to prevent the catastrophes they claim will arise?

Response. The IPCC has stated that a 2 °C. rise in temperature will cause an irreversible loss of the Greenland Ice Sheet. The IPCC suggests that there is greater than a 90% chance that the globe will suffer this temperature if greenhouse gases reach levels equivalent to 450 parts per million of CO_2. According to Flannery, the IPCC has concluded that the GHG levels reached 455 CO_2eq in 2005 and continue to rise; and that the IPCC will announce that conclusion this fall. As such, absent some form of geo-engineering to reduce temperatures or scavenge CO_2 out of the atmosphere, it is too late to prevent melting of the Greenland Ice Sheet, and the planet will suffer a 23 foot rise in ocean levels. None of the legislative proposals direct research on or use of solar radiation management to prevent catastrophic melting of the Greenland ice sheet. Thus, the goal of environmental organizations and legislative proposals to stabilize CO_2 levels will fail to prevent ocean level rise of mammoth proportions.

Question 3. Does geo-engineering make sense even if global warming is a natural phenomenon?

Response. That depends on the associated risks and benefits of global warming as compared with using geo-engineering to stabilize planetary temperatures. A

small increase in global temperatures appears to have net positive benefits for the world civilization and nature. A large temperature rise will cause massive geophysical change with equally massive net-adverse effects on world civilizations and massive upsets in nature.

Regarding effects on human civilization due to warming and concomitant sea level rise, a single meter rise in ocean levels would flood one-third of Bangladesh and force the relocation of from 25 to 30 million people. Similar effects would be felt in China at a two-meter rise in the ocean. A five foot rise in storm surge would incapacitate nearly all commercial harbors world-wide causing hundreds of trillions of dollars in damage. In light of these potential effects, a measured effort to stabilize global temperatures would be justified even if, for example, it caused small adverse effects such as minor drought in portions of the world. Current modeling of the potential adverse effects of solar radiation management, using high-tech particles to reflect the sun in only one wavelength and with no chemical reactivity in the upper atmosphere (stratosphere and troposphere), suggest no change in local climate (see Caldeira 2006).

The reverse of the question is also of interest. Would it make sense to warm the planet, using solar radiation management, if we confronted a new ice age? Would it be sensible to stabilize temperatures to prevent loss of Chicago, Detroit, Seattle, and the rest of developed land north of the Mason Dixon line—worldwide? Again, the negatives would have to be very large to refuse use of solar radiation management.

The appropriate approach to use of geo-engineering is to fund research on these tools now so that if they need to be deployed, we will have second or third generation technology on the shelf, rather than have to use unexamined proposals. For this reason, I have recommended directing $3.5 million toward research on solar radiation management (see my supplemental testimony which includes the geo-engineering framework requested by Senator Mikulski), along with research on how to create a body to manage international coordination of geo-engineering activities to ensure measured, responsible and efficacious stabilization of possible global climate extremes.

Senator CARDIN. Thank you for your testimony.

We will now hear from Pastor Richard Edmund, who is from the United Methodist Churches of Smith Island. As I mentioned earlier, Smith Island is the only inhabitable island in Maryland. It is on the Virginia–Maryland border, 225 sturdy people. Pastor Edmund is their spiritual leader and we thank him for that. We are pleased to hear from you.

STATEMENT OF RICHARD EDMUND, PASTOR, UNITED METHODIST CHURCHES OF SMITH ISLAND

Pastor EDMUND. All right. Thank you, Senator Cardin. It is an honor to be here, and also with Senator Mikulski, especially in light of the other distinguished panel members that came before me.

My name is C. Richard Edmund. I am the Pastor of the three United Methodist Churches on Smith Island, Maryland. I am here to speak for Smith Island, the planet, future generations, and how I believe God wants humans to interact with creation. Smith Island is located across from the mouth of the Potomac River, surrounded by the waters of the Chesapeake Bay. Our population is about 225 people spread among the three communities of Ewell, Rhodes Point, which you can see in the photograph up there, and Tylerton.

Because of our geographic location, we are certainly vulnerable to the effects of a rising sea level. Most of the dwellings are just a couple feet above an abnormally high tide or a storm surge from a hurricane. In 2003, Hurricane Isabel caused a storm surge which came into a few of the homes and covered most of the inhabitable land, and all of the marsh area.

A rising sea level would accelerate the effects of erosion which threaten parts of the island. The recent work by this Committee and the corresponding members on the House side is greatly appreciated in including the Smith Island Project in the recently passed Water Resources Development Act. Thank you.

Almost all the island families depend on harvesting from the water for their livelihood. The numbers of crabs and oysters are much less than earlier. Any climate changes caused by human activity can only diminish what God created and called good.

While I have not been on the island long enough to observe possible climate changes myself, older residents tell me that, number one, some houses that never or rarely had water in their yards now often experience that inconvenience during extra high tides. Number two, we do not have the winter blizzards or freezes that is within the memory of many islanders. Now, most winters, the total snowfall is less than six inches.

Number three, there is a wildlife presence now that didn't used to be there. The brown pelican is the largest example. They began settling this far north about a dozen years ago and now nest on the border with Virginia.

The independent folks of our community have been toughened over time from dealing with the elements of nature. Despite the difficult times for watermen, residents are determined to stay until forced to leave by the economy or the environment. Twenty-five years ago, experts said we wouldn't be here in 25 years. As one islander, Jennings Evans, summed it up, "We will be here as long as the Lord wants us here."

But reports of potential sea level rises are daunting. I know both of you and others have been to Greenland recently and seen firsthand the beginning of large-scale meltdown. Predictions of a 20 foot to 23 foot sea level rise would affect many millions of people worldwide. A rise of three feet would likely be the end of practical living on Smith Island.

A recent movie, which I was with at the premier with Congressman Gilchrest, was entitled "We Are All Smith Islanders." It highlights that while our area is the oft-referred-to canary in the coal mine, all of us are vulnerable in some way to any human-involved climate changes.

In 1813, one of the future members of the Senate, Army General William Henry Harrison of Ohio, received a war report from Commodore Oliver Perry after the battle of Lake Erie: "We have met the enemy and he is ours." For Earth Day in 1970, Walt Kelly changed one word in order to point out where the blame originates with our environmental problems. His cartoon character, Pogo, says: "We have met the enemy and he is us."

I urge this Committee to strongly address this issue. It threatens our security, and I believe disrupts God's instructions to Adam and Eve to work the Garden of Eden and take care of it.

On a kayak trip I took down the Susquehanna River, a man in Northern Pennsylvania asked me, "Are they mad at us down there?" He was wondering if the acid mine drainage, silt runoff, and other pollutants originating in the upper river area had upset those living around the Bay. The larger question is whether future

generations downstream in time will be angered with us for not doing more to stem the changes that seem inevitable now.

One of the reasons I feel good about being here today is that my daughter has brought my four oldest grandchildren, Bryn, Elisabeth, Brooke and Caroline here with me. I trust that part of my legacy to them will be that they will tell their grandchildren that in September of 2007 their great-great-grandfather spoke to this Committee to address the issue of global warming and the long-term consequences. I want them to know that I did what I could. Members of this committee, I trust you will do the same.

Thank you for the privilege of speaking.

[The prepared statement of Pastor Edmund follows:]

STATEMENT OF RICHARD EDMUND, PASTOR, UNITED METHODIST CHURCHES, SMITH ISLAND, MD

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1. Some houses that never or rarely had water in their yards now often experience that inconvenience during extra high tides.

2. We do not have the winter blizzards or freezes that is within the memory of many Islanders. Now most winters the total snowfall is less than 6 inches.

3. There is wildlife present now that didn't use to be there. The brown pelican began settling this far north about a dozen years ago and now nest on the border with Virginia.

The independent folks of our communities have been toughened over time from dealing with the elements of nature. Despite difficult times for watermen, residents are determined to stay until forced to leave by the economy or the environment. Twenty five years ago, experts said we wouldn't be here in 25 years. As an Islander, Jennings Evans summed it up, "We'll be here as long as the Lord wants us here".

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The larger question is whether future generations, downstream in time, will be angry with us for not doing more to stem the changes that seem inevitable now.

One of the reasons I feel good about being here today is that my four oldest grandchildren, Bryn, Elisabeth, Brooke, and Caroline, are here with me, along with my daughters. I trust that part of my legacy for them will be that they will tell their grandchildren that in September of 2007 their great great grandfather spoke to this Committee to address the issue of global warming and the long term consequences. I want them to know that I did what I could. Members of this Committee, I trust you will do the same.

Thank you for your time.

RESPONSES BY PASTOR RICHARD EDMUND TO ADDITIONAL QUESTIONS FROM SENATOR CARDIN

Question 1. With a population of just 225 people and three churches, Smith Island must be home to people who really value their faith. You have spoken eloquently today about how faith sustains the people of Smith Island. Would you please take a few minutes more to talk about how your faith motivates you to be involved in issues such as this one, especially the role you see among people of faith and their stewardship responsibilities for God's creation?

Response. A lot of my sense of responsibility for caring for God's creation comes from the book of Genesis. In chapter 2 verse 15 God instructs Adam to "work and keep" the Garden of Eden. Surely this is a guideline for the rest of our environment. While we have dominion over the earth, that doesn't mean we dominate and subject it to whatever purpose seems best for us for our immediate future.

After the Flood God makes a covenant with Noah and his descendants never again to destroy the earth by a flood. In this passage in Genesis 9, verses 9 and 10, God includes "birds, livestock, and all the wild animals" in this binding agreement. They are our partners in this covenant with God, and I believe we need to defend them against harm. There is Biblical support for this position in Proverbs 31:8–9 where we are told to "speak up for those who cannot speak for themselves, . . . defend the rights of the poor and needy." While this is directed primarily toward other humans, I believe God would want us to defend His creation and our partners against harm due to our greed. Nature is often without defense from our modern machinery and waste products from power plants, homes and industry. It must please God that some are speaking up for the part of God's creation we are intentionally and unintentionally changing. As I said in my testimony, God called Creation good, and we can't make it better.

We on Smith Island certainly use our share of energy and contribute to global warming, but I believe that folks like watermen and farmers who work with nature have a greater appreciation for being good stewards of God's creation. It is their faith in God and what I see as my responsibility to them, and the rest of the world, that helps form my faith response on this issue of global warming.

Question 2. In your testimony you relate a wonderful story about a conversation you had with someone who lived 'up-watershed' in Pennsylvania who expected criticism for the pollution that was making its way down into the Chesapeake. Your gracious answer to him was a good lesson to all of us about finding solutions, not assigning blame. But I want to focus on the challenge that you then issued to all of us. You say that we need to answer the challenge of those who live not just downstream today, but those who live in downstream generations. I agree. Would you take a moment to talk about the responsibility we have to future generations to address climate change today?

Response. Many Native American tribes traditionally considered how their actions would affect those who came after them for seven generations. There is a statue dedicated to this thought on the banks of the Susquehanna River which provides one-half of the fresh water flowing into the Chesapeake Bay. It was further upriver from that point that the question was asked about responsibility for what has happened to the Bay and beyond. I have a feeling that those in the generations to follow ours will wonder "What were they thinking?" when those in positions to make a difference stood by and watched as pollutants in many forms poured into our air, land

and water and did little or nothing to stop the effects with which they will then have to contend.

As a heavily loaded train or a large ship takes a long distance to slow down and stop, the earth changes we seem to have initiated will take many years and maybe generations to slow down. It is an almost complete unknown what will really happen after we are gone. The wildly differing estimates of sea level rise attest to that factor in the equation of global change. But each little step will help and we can't be intimidated by the enormity of the problem.

A couple years ago I testified for the Maryland legislature about why power plants should restrict their emissions into the atmosphere. In addition to the Senate hearing where I was very honored to speak to this issue of global warming, I will share that with my children and grandchildren, and I trust they will pass along to their children in turn, that I did try to help stem what seems like a runaway train that they will have to figure out how to stop, or how to live with the consequences. We all can do more to stem the changes that will inevitably come, but our legacy to those who come along after we are gone, should be that we tried to make a difference.

Senator CARDIN. Thank you for your testimony. We welcome your family. I think it is a fitting conclusion to this panel, and tells us the responsibility that all of us have in trying to get the Federal policies correct.

We will start the questioning with Senator Mikulski.

Senator MIKULSKI. First of all, I just want to thank every member of the panel for not only their contribution to this hearing, but what you do every day in terms of the vitality of the Bay, in terms of what you bring to the table, whether it is scientific commentary, pastoral stewardship, or advocacy.

Dr. Schnare, thank you very much for bringing the geo-engineering information. We will come back to it in time, but I would just invite you, if you have a framework that you would like to bring to my committee's attention, we would welcome this, because I think it will be a topic that will move on the global screen. I have questions and yellow lights about it. But rather than us giving our opinions about it, let's go beyond opinion and go to sound data and research, which is what we have been talking about here today.

Dr. SCHNARE. I would be happy to do that.

Senator MIKULSKI. I believe that anything dealing with global warming, and any changes, has to deal with, number one, the right diagnosis and the right prescription. Then you need the political will. Political will will only come if people think they are affected.

Now, Pastor Edmund, when I hear your testimony and look at the fact that there are now only 225 people on Smith Island, when it used to have a much larger population, the fact that people leave the island every day to commute into Crisfield, taking jobs, for example, at the prison so that they could have health care and a reliable revenue stream, while the men are kind of foraging for crabs.

My question to you, and I know you have been part of a covenant approach, et cetera, tell me why are so many people leaving the island now on a permanent basis?

Pastor EDMUND. It is complicated to answer, as global warming is. Some of them leave because it is a difficult situation for their young people to commute back and forth each day to school. It is a one hour boat ride each way, and if they want to be involved in sports activities and other activities.

Senator MIKULSKI. Let's go to the economics. Is it the fact that there is a decline in oysters, or what?

Pastor EDMUND. There are certainly many of the younger people that are not deciding to get into the watermen industry. It is a big output financially to do that. The future doesn't hold strong for a good harvest from the crabs or the oysters, so some people are leaving for that reason. Some people are going and working on barges and tugs. Quite a few people do that for the consistent income and also for the benefits provided, because of the difficulty to continue crabbing.

Senator MIKULSKI. So two things: No. 1, the concern about reliable income; and No. 2, reliable income is usually based on the way they earn their living, and the way they earn their living was off primarily crabbing and oysters. Isn't that right?

Pastor EDMUND. Yes. I would say maybe 90 percent of the income for just people living on the island comes from the watermen business.

Senator MIKULSKI. Let's go to you, Dr. Boesch. The Wildlife Federation put out this report, and we welcome it. But how long have you been studying the Bay?

Pastor BOESCH. A little over 25 years.

Senator MIKULSKI. Twenty-five years, and you have everything from peer measurements that go back 100 years, to your own research team. Now, in this report, as Senator Cardin has raised, oysters and crabs are part of our identity. They are also an important part of our economy, and we know that just if we look at watermen alone, let alone the multiplier part, we are talking about what was once thousands of people.

So here is my question. Given temperature rise, the change in chemical composition possibly, as a colleague mentioned, what now are there indications will happen to crabs and oysters, say, in the next—let's take crabs and then go to oysters—over the next 5 years? Not the worst case scenario, but a mid-case scenario. And where do you think we will be in, say, 5 years or 10 years if current trend lines continue?

Pastor BOESCH. Well, of course the predictions are difficult, particularly, as they say, about the future. So it is hard to draw firm conclusions. However, we can look at the things that we think are the most likely to happen as the Bay continues to warm, and sea levels continue to rise. The threats to those two resources are primarily these.

First of all, juvenile crabs, depend on the Zostera or eelgrass beds in the lower bay that we have talked about. Just 2 years ago, we almost lost them. At the end of a very warm summer, populations were down to a very low level. Young crabs also depend on tidal marshes, which are very much in jeopardy as sea level rise accelerates. So for crabs, the habitat losses are a really critical problem. The prognosis doesn't seem to be promising. We won't lose crabs altogether, but the number and productivity of blue crabs will probably be diminished.

Second, with respect to oysters, as the Bay deepens as sea level rises, more ocean water coming into the Bay. If there is a fixed amount of fresh water coming in from the rivers, this means the salinity lines move up in the Bay. As you know, Senator, that is really a serious problem for oysters because of the oyster diseases

which are controlled by salinity. So as salinity increases, the diseases will progress farther up the Bay.

Senator MIKULSKI. So is it conceivable that the economy that we know, that if we were sitting at one of our famous crab houses, and I won't mention them by name. It is like saying who is your favorite child. But if we were sitting in one of the crab houses in Maryland, it is conceivable—

Senator WARNER. Or Virginia.

Senator MIKULSKI. Or Virginia.

Senator WARNER. Thank you.

Senator MIKULSKI. You know, we still haven't had that crabcake cook-off that you challenged me with.

[Laughter.]

Senator MIKULSKI. But the fact is that we could look to more and more importing because we cannot meet the demand now. Is that right?

Mr. BOESCH. That is correct. As you know, Senator, that is happening now with the importation of both oysters and crabs to meet the local and regional demand.

Senator MIKULSKI. Which would be a decline of our economy and our whole way of life. I mean, the watermen.

Now, let's, if I could just turn from my last question, to Will Baker. Will, and all the panelists, do you remember when Isabel hit and we had the surge in the Bay and the water came up. In my mind, we got a taste of what rising sea level would mean. It was temporary, but it was devastating. Will, take me on a tour down the Bay, starting at Crisfield and ending in Baltimore. As you see the temperature rise, what would you say is the impact, just physically, on Crisfield, Hoopers, Annapolis, and Baltimore?

Mr. BAKER. Well, Senator, we released a climate change report this summer. On the cover is a picture of downtown Annapolis during Hurricane Isabel. I think that picture speaks 1,000 words. That is what you are going to see in Crisfield and Hoopers Island and St. Michaels and all the way up into Baltimore, is streets flooded, resources flooded, economic damage. I think it is critical.

You mentioned the farmers. It certainly impacts there. With greater storms and runoff and erosion, you are going to have more sediment loads in the Bay. So I would add that to what Dr. Boesch said is an impact.

Senator MIKULSKI. And agricultural legacy issues, in other words, no matter what you have been able to work out constructively with agriculture and poultry, what will run off will not be pristine topsoil.

Mr. BAKER. There is no question. We could face severe economic, environmental, recreational, human health issues.

Senator MIKULSKI. But if we picture Hoopers Island, that would probably go under water.

Mr. BAKER. The islands of the Bay are already disappearing, and you would see that accelerate and probably come to a conclusion in our lifetimes.

Senator MIKULSKI. Now, let's picture Annapolis, from the Naval Academy to Main Street. During Isabel, it just flooded out. We had $42 million worth of damage at the Naval Academy. It flooded out

the entire power plant at the Naval Academy, and classes had to be moved to a variety of other settings, just as an example.

Can you describe what Annapolis would look like?

Mr. BAKER. Absolutely. That is what you would see more of. Fells Point, your hometown, underwater. So there is human, economic, and environmental health impacts from all of this.

Senator MIKULSKI. Well, I will stop with my questions.

Senator Cardin, do you remember how you, both as a House member and in the General Assembly, remember how we had to deal with beach erosion in Ocean City? So we had to deal with a lot of remedial work. It seems to me we have to look ahead to, if global warming is so, and water will rise, not at the draconian rate of say 20 feet, but 2 feet, then they are not going to be able to get insurance for their buildings; being able to pull back from the water. I don't know how you pull back the Naval Academy. I really don't. And all that has been around it would be significant.

When you think of Baltimore, what would run off into the Bay, because you have agricultural legacy, but we have industrial legacy that could cause significant pollution. But there would be no remediation to protect our land resources.

So I will stop now, because to me the best prevention will be working internationally, and of course, our own national solutions with Governors. But again, I am going to stop. We really want to thank you. I am sorry I couldn't ask each and every one of you a question.

Senator CARDIN. Senator Mikulski, thank you. As I pointed out, AllState already has stopped insuring, and many of the insurance companies. If you live in the coastal areas, it is tough to get insurance today because the insurance companies understand the risk, not only the risk from sea level change, but it is climate change. They understand that. They understand that they are not willing to risk their financial investments. It is causing real hardships for people who live in coastal areas.

The chart that we brought here shows a one meter, the red is a one meter increase in sea level. Dr. Boesch indicated two to four feet would be what you could reasonably anticipate. So that would be about the average increase, but then red would be under water. So it gives you an indication of the serious threat this region has from sea level change increases.

Senator Warner.

Senator WARNER. Thank you, Mr. Chairman.

A question for Mr. Baker. The environmental bill that Senator Lieberman and I are working on does have a provision for the Bay. As a matter of fact, there is quite a liberal provision in there for distribution of funds to the interests of fishermen, trout streams. We have a lot of environmental funding streams going out. But let's assume we have a block of money, and it does pass through for the Bay, what are the mechanisms by which we get it down into the proper priorities for the Bay? Congress can't be expected to know the details to make that assessment.

Should we sort of divide the money between the several States that are surrounding the Bay? It may be somewhat disproportionate for Maryland and Virginia, given that their shorelines consume a good deal of it. How would you go about the mechanism by

which we—the conduit for the money to the Bay form the cap and trade proposal now under consideration?

Mr. BAKER. The good news, Senator, is that thanks to scientists here today, Dr. Boesch, Dr. Pyke and certainly all those behind them, the science is very precise in terms of how the money could be spent most effectively. I will just touch on one area that I mentioned in my testimony which has benefits also for global climate change because it sequesters carbon.

To use some of this money to help the farmers put the best management practices on their land, that have proven to be the most cost-effective way to reduce a pound of nitrogen from coming into the Chesapeake Bay, just to take that one pollutant, seems to me the place where now much of the focus should be.

Thanks to the good work in the Commonwealth and in the State of Maryland, we have come a long way towards addressing sewage treatment plant upgrades to the state of technology. But now we need to turn to the agricultural sector. They are meeting us more than half way. They want to do what is right. They want to invest their own money, but they need assistance.

There are numerous mechanisms whereby those decisions can be made to get the money to the most effective areas in keeping with science.

Senator WARNER. Well, is it better to say to the State of Virginia and Maryland, "Here is the money; you go back and direct how your farmers do it, not the Federal Government." If I might draw on a modest bit of experience. I spent many of my summers as a boy on farms growing up, back in the days when we didn't have many tractors. They are all big dray horses we used. And I then owned quite a few farms in my lifetime. So I have always been interested in it.

Farmers are very independent. When you step on their land, that is their sovereign territory. Now, it doesn't take a genius to figure out that when you are plowing, you expose the soil, but you have to do it—although we do more sod planting now—but plowing exposes a very dangerous time for the drain-off. But you can plug up the tributaries and so forth it drains off into.

I don't see why it takes so much money to try and help the farmers do what seems to me is obvious to them. They have farmed that land and their forefathers in most instances have farmed it, too.

Mr. BAKER. Well, I think it is competing——

Senator WARNER. It's not rocket science, is it?

Mr. BAKER. I think it is competing in a world economy that is trying to get more and more production out of the same acre of land.

Senator WARNER. I agree with that.

Mr. BAKER. We see that happening all the time in terms of the intensity with which land is farmed now, dramatically increased even for the last 40 or 50 years, so more fertilizers, more herbicides, more intense croppings. I think that is really at the root of why it is so much more difficult today than it may have been in the past.

Senator WARNER. Any other suggestions? I think you are well taken and you are correct about the advancement in science in trying to take less and less tillage land and put it to good use.

Dr. SCHNARE. Senator, the Thomas Jefferson Institute has been working very hard to try and find ways to encourage farmers to transition to never-till farming. We don't begin to take responsibility for what has happened, but we are very pleased to report what has happened. As recently as 5 years ago, fewer than 80,000 acres in Virginia were in the mix. It is now up to about 150,000 acres out of 1.1 million. You can reduce nutrients by 90 percent by using these advanced techniques.

Senator WARNER. You mean nutrients escaping from the farmland?

Dr. SCHNARE. Exactly.

Senator WARNER. You don't have the streams and tributaries feeding into the——

Dr. SCHNARE. Yes, sir. Exactly that. But what we found it takes, because farmers make money doing this, it is to their benefit to do it, it is rocket science. It is a difficult change in farming, and we found, and have worked very hard, for one, I am pleased that the State legislature acceded to this, to increase funding to the technical experts in the State Farm Bureaus and the like, who can be the agents of change to help farmers transition. They haven't done it immediately, but it is growing. The number one most productive corn farmer in the United States has been doing never-till farming for over 15 years.

Senator WARNER. You mean sod planting?

Dr. SCHNARE. No, Senator, I mean corn production Virginia.

Senator WARNER. No-till.

Mr. SCHNARE. He doesn't even use winter cover crop at this point.

Senator WARNER. Is that right?

Mr. SCHNARE. He is right on the Rappahannock. He is a remarkably good farmer and he is a model for the entire State. We are going to encourage more and more of that. That is why we work with the Chesapeake Bay Foundation and others to try to bring these methods forward over the last several years.

But keep in mind, and this is important to understand, regardless of how we get them the money, we have a short-term problem as well as a long-term problem. The short-term problem is the foot or two ocean rise. The second problem is the many feet ocean rise. They are two different kinds of problems.

I extend again the opportunity to inform you, as Senator Mikulski has asked us to do, to talk about geo-engineering, which will address these, some in the short term and some in the long term. Those are not State challenges. Those will have to be Federal and international.

Senator WARNER. I appreciate that testimony, and I may have been a little off the mark on that. I accept your answer as being the correct one, that there is a measure of rocket science in this and we have to help our farmers learn it.

Could I have one more quick question? A little bit of philosophical approach to this whole subject of climate change. I am a relative newcomer. I have been on this committee I think 20 odd years now, but we have really come into focus on this issue. I have teamed up, and I am ready to step out and take risks and politics be darned. We are going to try and drive this bill through.

But in fairness to other colleagues on this Committee and throughout the Senate, there is still a lot of question marks about global climate change, is it real, what are the unknowns. I mean, it caught my attention when Mr. Boesch, his opening statement, very well drafted, and I will repeat it: "Chairman Boxer, members of the Committee, I am Don Boesch. I am pleased to appear before you today to address what is known." That is the key phrase, "what is known about the impacts of global climate change."

Now, any bill like cap and trade is secretly reaching into the pockets of Mr. and Mrs. America, the working people. There is nothing that is of greater value next to a man's home and his family, than his car. And that is becoming a more costly means of transportation because of fuel costs. Every home has got to go through a measure of heating or cooling, as the case may be, during various times of the year.

These costs are going to begin to creep, and the public I think is going to say, "OK, let's give it a chance; I will continue to pay." But if we try and push too far in our initial charge forward on this issue, and we overstep technology and overstep what we know and how to go about correcting it, I think the public might rebel and we will all pull back and then have to start again, and I don't know when we would get the momentum to start again.

So I do it with a measure of caution. No matter how committed you are individually, and I am and certain members of this committee, there are those who way to say let's go at a pace where we are secure, and then consolidate our gains, and then move ahead again.

Now, it is clear that we have to put down some very strong markers. We can't go about this thing half-hearted. But whatever we do, let's go at it with a full heart, but only try and gain that amount of ground in our first charge out of the trenches and over the top into the face of the unknown, and then consolidate and then do it again.

Just philosophically, do you all share that? Or do you have a difference of views? Let's just start at your end and go the other way for a change.

Pastor EDMUND. Well, we certainly want to be correct in what we are doing. It is a fine line as to whether we delay long enough to make 100 percent certainty as to whether this climate change is actually going to occur. Of if we wait too long, and then it is so much of a larger job ahead of us.

But I think if we apply reasonable measures, it is better to err on the side of caution. We certainly for a couple centuries now have been putting a lot of pollutants into the air that have to have some sort of effect, I believe, on the climate in the long run.

Senator WARNER. I agree with you. I am willing to take a measure of risk, not concerning my political risk or anything like that.

Pastor EDMUND. Right.

Senator WARNER. Take a measure of risk, but we just want to capture that high ground that we can take based on some pretty solid data as to the effects of climate change and the degree to which technology and modern science can put in corrective measures.

Mr. SCHNARE. Thank you, Senator. I think the question of incremental approaches crashes on the rocks of the time scales with which we are operating. If we are to prevent 550 parts per million of CO_2 in our atmosphere, which is considered the point at which we hit the first tipping point, the inevitable full melting of the Greenland ice sheet, some argue, including Nobel laureate Paul Crutzen, that it is already too late, and that any attempt to prevent that is nothing more than, in his words, "a pious hope."

If what I am hearing from you is that the 80 percent reduction needed worldwide is too much of a first step, and since China and India refuse to do it, it probably is, then I think what you have to examine is what can we do—we know there are acute things to do for the first 20 years. We know they are affordable. But they will not solve the initial problem. We are going to need a couple of centuries to move away from carbon-based fuel, which is why I have raised to the Committee this concern about geo-engineering, that someone will use, but which is not now being managed or even contemplated on how we would manage this process.

Senator WARNER. Well, I don't mean to be half-hearted, but just philosophically I will take into consideration your views.

Mr. Avery.

Mr. AVERY. The correlation between our temperature record over the last 150 years with CO_2 is very, very weak. The correlation with the sun spot index is very, very strong. I think that, with all due respect to the power of the Congress, you are headed for enormous anguish, frustration and misspent capital in this effort to reduce greenhouse gas emissions. It will not halt the temperature cycle.

Mr. BOESCH. Well, first the good news. We have a good starting point, because I think we have all agreed, despite the difference of perspectives, that the world is warming. So let's get on beyond that discussion and figure out how much of the warming is due to humankind, and how much is due to natural cycles.

The fact of the matter is that we have added greenhouse gases into the atmosphere over the last 30 years that warmed the earth 10 times more than the variation in the solar energy reaching the earth. So although Mr. Avery indicated that the solar activity does affect our climate, we are going to a new era beyond that. We are already in a warm period and we are now taking it outside of what the earth has seen over hundreds of thousands of years.

So I would agree that time is not on our side. We do need to make some positive commitments and actions, but we don't have all the solutions in hand. Whether it is geo-engineering or carbon sequestration, all of these things are going to take time and investment.

However, another point that Dr. Schnare made, is that there are lots of things that we can do now to sort of reverse the upward growth in emissions and then reduce them. That is why States have formed climate commissions, including the one Governor O'Malley talked about, that are developing goals from a State perspective. The States are setting 2020 goals for emissions reductions, something that we could actually begin to strive to achieve specifically. What they are concluding is that once you look at it,

it is feasible to return to levels of emissions that were present in 1990.

Guess what? This fear that it is going to bankrupt us, we can't afford it, goes away when you start to look at ways to achieve these goals. The State of Arizona recently completed its plan. The State of Arizona is one of the fastest growing States in the Nation and Lord knows, it has huge demands for air conditioning. It estimated that it could reduce its greenhouse gas emissions back to 1990 levels even with all of its growth and economic development, and actually save for their economy $5.5 billion—not cost, but save. There are up-front investments. There are investments that have to be made in terms of alternative energy sources. But most of the other things we can do actually benefit our economy and benefit families, because they reduce energy consumption.

Senator WARNER. The point is well taken. I didn't mean to consume time. I think I hit sort of an interesting note.

Senator CARDIN. No, no, I want to give you the chance for the last two to respond. I think it is a very important question.

Senator WARNER. Let's do that.

Senator CARDIN. Because we need to figure out what is the practical way we can get this accomplished.

Senator WARNER. That is correct.

Mr. PYKE. Thank you. I will try to answer very succinctly.

One, emissions choices make a difference. That is important. Two, wearing one hat, part of my professional life is in the building sector. It is an industry that is transforming itself to meet higher levels of performance. This not so much about cost as it is about fixing a fragmented and complicated industry. That is something we can do and we can all profit from in various ways.

The third and more important issue, or equally important issue, is that a lot of the things we talked about with regard to the Bay are process improvements. This is about electing to make a different decision in how we are managing our resources. As Dr. Boesch had said, we are looking at changing conditions. Thus, it is irresponsible to carry out our responsibilities as if climate wasn't changing. And so as we carry out the Clean Water Act, as we carry out the Endangered Species Act, as we look at NEPA, those are situations where it is now responsible. The standard of care is shifting so that we should ask our agencies to include that in their decisionmaking process explicitly. That can be done immediately.

Senator WARNER. Good.

Mr. BAKER. I truly believe the costs will actually come down to the general public. In the Chesapeake Bay Foundation's energy efficient building, for instance, we are saving $75,000 a year in energy costs. So I think conservation of energy is a great cost saving.

Senator WARNER. I agree.

Mr. BAKER. But secondly, maybe here is the philosophical part, let's accept for a moment that global warming is not going to happen. And then let's look at all the strategies that have been put forward to address global warming. All of them make great environmental sense even if they are not to address global warming. I will just cite my friend Jim Woolsey, who is such an advocate for energy conservation. His motivation is because he believes global

warming is real, but also energy independence for this Country and the great benefit that is to national security.

So there are lots of other benefits of the strategies we have all been talking about beyond global warming.

Senator WARNER. I share your admiration for Jim Woolsey.

I thank the Chair. I thank my colleagues. What an excellent hearing we have had this morning.

Senator CARDIN. Senator Warner, thank you. I think the last point that Mr. Baker made is that there is more unity in this issue than one might expect, for different reasons. I think there is a strong need for the environmental issues, including the Chesapeake Bay, but also national security on energy independence, and also economic issues because we can save a lot of money for our economy.

Following up with what Dr. Boesch said, there is agreement, I think consensus, that we are getting warmer, and warmer is not good for the health of the Chesapeake Bay region. Whether it has to do with the warmer waters, which is affecting the life on Smith Island because it affects the watermen's livelihood, or whether it affects people who want to live here because they want to go out on the weekend and catch rockfish, which might not be here in the future if we are not careful as to what happens with the warming of the Chesapeake Bay, whether it is sea level increases, which certainly is having an impact on the life of this entire region, or whether it is storm conditions which bring us more unpredictable weather, which is affecting the ability not only to get insurance, but the safety of your family.

These are all issues that I think we need to deal with. I do think that there is also general agreement with what Dr. Boesch said, and that is, sure, we go through cycles of warming, but there is normally stability in those cycles. And then in the last 50 years, we have seen something somewhat dramatic as to what has happened. Although there may be some argument as to what impact the greenhouse gases have on that, it has been the major variable over the last 50 years, the amount of emissions of greenhouse gases. So it is something that is a major concern as to how we are going to figure out what is right for the Chesapeake Bay and our environment, but also what is right for our energy policy in this Country.

I think Senator Warner's point about coming up with a practical solution is important. It is not only important from the point of view of getting a bill passed in the Congress and signed by the President, but we need also to be credible for international leadership. The United States has to get back in the game. We do need to be able to exercise international leadership as it relates to what is happening in China and India and other countries because obviously that has an impact on what we are doing.

So I think these are all interrelated, but clearly the people in the Chesapeake Bay region are directly affected by these policies.

I thank all of you for the manner in which you have made your presentations today. I agree with Chairman Boxer, I think this has been a very, very important hearing for all of us who are trying to do what we can to preserve a way of life for the people of this region. And to Pastor Edmund, I will conclude with you. Your grand-

children should be very proud of what you are doing. On a typical Sunday, you should know that Pastor Edmund needs to use a golf cart and a boat in order to get to the three churches on Smith Island in order to provide the spiritual leadership to that community, which is just an inspiration to all of us.

We thank you very much for all of you being here. We look forward to working with you.

The Committee will keep the record open for one week.

If there is nothing further?

Senator MIKULSKI. Mr. Chairman, Acting Chairman, I would like to just thank again everyone who participated, and all the hard work that went into it.

What I would like to just comment is that I was very pleased that maybe I have had a modest impact on public policy by my presence. But I have obviously helped you move up and in 2½ hours become Chairman.

[Laughter.]

Senator MIKULSKI. We have had a good day. Thank you very much.

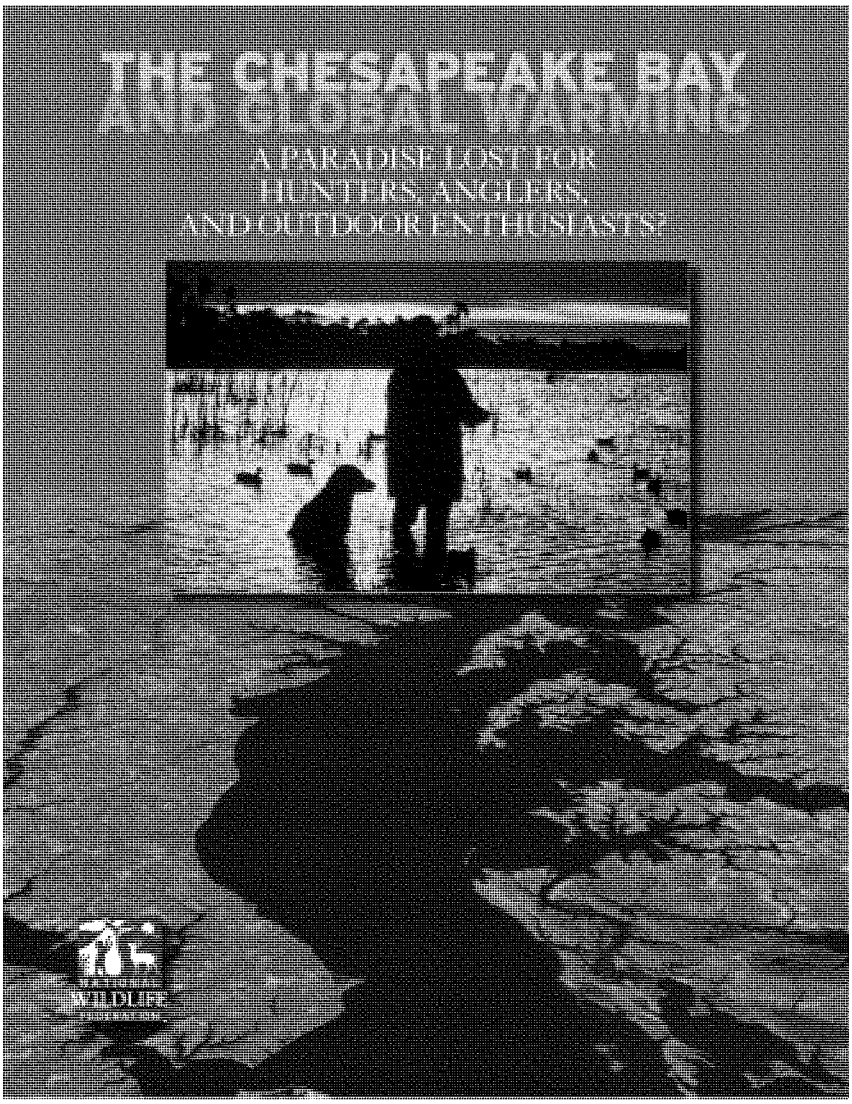
Senator CARDIN. Maryland is in a good position right now.

Senator MIKULSKI. As Louis Goldstein would say, "God bless you all real good."

Senator CARDIN. The Committee will stand adjourned. Thank you all.

[Whereupon, at 12:04 p.m., the committee was adjourned.]

[Additional statements submitted for the record follow:]


THE CHESAPEAKE BAY
A PARADISE LOST FOR
HUNTERS, ANGLERS,
AND OUTDOOR ENTHUSIASTS?
NATIONAL
WILDLIFE
FEDERATION

The Chesapeake Bay and Global Warming:

A Paradise Lost for Hunters, Anglers, and Outdoor Enthusiasts?

September 2007

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Larry J. Schweiger
President and Chief Executive Officer
National Wildlife Federation

Acknowledgments

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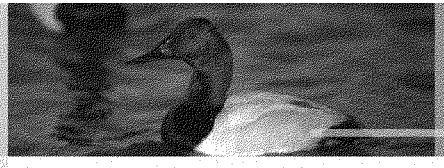
FRONT COVER: U.S. FISH AND WILDLIFE SERVICE (GREEN), MAP (NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA); LEFT U.S. GEOLOGICAL SURVEY (USGS). TOP RIGHT: USFWS



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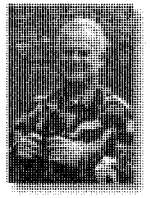
NWF's mission is to INSPIRE Americans to PROTECT WILDLIFE for our CHILDREN'S FUTURE

Message From The CEO



I have fond memories of trolling the lower Potomac on foggy autumn mornings, while nearby watermen "tonged" for oysters and gulls swarmed the skiffs. The Chesapeake Bay has long held a special place in my heart. From a home we enjoyed on Maryland's Kent Island, I have developed a deep appreciation for the natural beauty and outstanding recreational opportunities offered by the bay. I have fished and hunted there for more than thirty years.

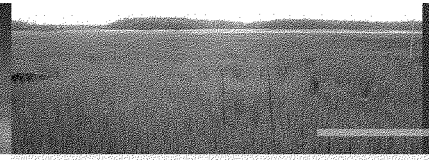
My personal devotion to the Chesapeake Bay has motivated professional efforts to protect this national treasure. Beginning in the late 1970s, I assisted in the most comprehensive assessment of the bay to date. During the 1980s, I served on the board of the Citizen's Program for the Chesapeake and chaired a Point Source Working Group that helped develop an "action agenda" advancing measures to restore the Chesapeake Bay. Later working at the National Wildlife Federation, we organized a major conference, "Chesapeake Bay—A Pennsylvania Connection," which encouraged the Chesapeake Bay Foundation to launch its Pennsylvania office focused on watershed restoration. In 1995, I joined the staff of the Chesapeake Bay Foundation, where we initiated an effort to better manage the blue crab and protect its deep water corridors. As CEO of the Western Pennsylvania Conservancy, I proposed that the Commonwealth launch a conservation bond fund that evolved into "Growing Greener," a program to fund watershed restoration along Pennsylvania's many waterways. Growing Greener continues to pump tens of millions of dollars annually into various river and stream clean-up projects.

My deep concern about the future of the Chesapeake Bay continues to guide me from my post at the National Wildlife Federation. I also have an abiding respect for the many professionals who have spent their entire careers restoring the bay. I understand the importance of broad collaboration at this critical moment. Like it or not, global warming will be the defining issue of the 21st century. In its wake, the things I love most about the bay will be in jeopardy. Unless we address the root causes of global warming, rising sea levels will wash away islands, destroy critical wetlands, and render current shorelines unrecognizable. More-intense storms will increase sediment and nutrient runoff. Warmer water will change the entire ecology of the bay, pushing out cold-water species and allowing an influx of warm-water and invasive species. Without decisive action to address global warming, all the hard-fought progress made by so many to restore the bay could be lost.

The challenge is significant. Fortunately, we can minimize the impacts of global warming on the Chesapeake Bay. We can steer clear of the worst impacts by taking action now to reduce our global warming pollution by just 2 percent per year. And, we can take steps to help humans, along with the fish and wildlife of the Chesapeake Bay, cope with those climate changes that are inevitable. We don't have time to waste. And, it will require the action of all of us. *The Chesapeake Bay and Global Warming: A Paradise Lost for Hunters, Anglers and Outdoor Enthusiasts?* offers a plan of action that can help restore the bay to its full splendor. It is my fervent hope and belief that we will be successful. Our children and grandchildren are counting on us.

Sincerely,

Larry Schweiger
President & Chief Executive Officer



Executive Summary

Global Warming Jeopardizes Cherished Outdoor Traditions in the Chesapeake Bay Region

Global warming is causing major changes to natural systems today. Around the world, countries and communities are feeling the effects and searching for the right responses. This report by the National Wildlife Federation focuses on the very real threat that global warming poses for fish and wildlife in the Chesapeake Bay region. The report synthesizes recent scientific studies and observations from the field to offer a blueprint for action to overcome the problems spawned by global warming.

Fish and wildlife in the Chesapeake Bay region will be directly affected by several climate changes that are already underway:

- **Warmer air and water in the Chesapeake Bay region** will alter the composition of species that can live in the bay, contribute to worsening dead zones and harmful algal blooms, enhance marine diseases, and encourage expansion of harmful invasive species such as nutria.
- **Rapidly rising sea levels** will inundate coastal marshes and other important habitats that are important for fish and waterfowl and make coastal property more vulnerable.
- **More-extreme weather events, including floods, storms, droughts, and heat waves** will lead to more polluted runoff into the Chesapeake Bay, hurt water quality, and make the outdoor experience increasingly unacceptable for people.
- **Changing climate across North America** will affect breeding grounds and migration patterns for waterfowl, such that fewer birds make their way to Chesapeake Bay each year.

The bottom line is that these changes to natural habitats in the Chesapeake Bay region put treasured outdoor traditions—from sportfishing and waterfowl hunting to clamming and lazy days on the beach—at great risk.

The Major Investments in Chesapeake Bay Restoration Could Be Lost Due to Global Warming

Over the past quarter century, billions of dollars have been invested in restoring the Chesapeake Bay watershed. Sportsmen and women in particular have been strong supporters of responsible land use, wildlife, and fisheries management, helping to restore populations of popular fish and wildlife species. But, global warming puts new stresses on the bay's habitats, in some cases making it harder to reach conservation goals.

Many efforts currently underway to restore and protect the Chesapeake Bay's habitats—such as reducing nutrient pollution to managing coastal development—may also help fish and wildlife deal with global warming. To be successful, these conservation programs will need to consider the additional stressor of global warming, and in some cases, new initiatives will be required.

Solutions Are Available

The problems of global warming is daunting. Fortunately, solutions are at hand. The time for

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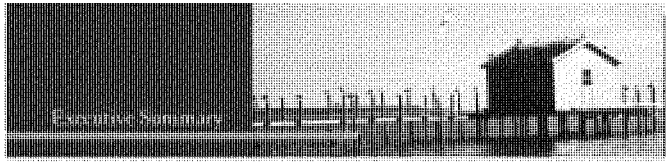

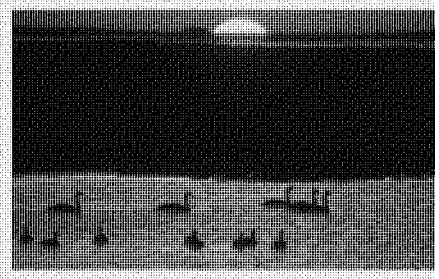

Reduce Global Warming Pollution

[illegible]

- The U.S. Congress and the administration should place mandatory limits on the nation's global warming pollution at least 80 percent below 1990 levels by 2050.

Provide Adequate, Dedicated Funding for Conservation

[illegible]

- The U.S. Congress and the administration should pass a comprehensive and multi-faceted strategy to reduce global warming pollution, with roughly 10 percent of the revenue from its sources of GHG pollution of the proceeds earmarked for land conservation. The funding should be spent on adaptive conservation strategies, for natural resource management, on planning for new habitat and other possible impacts of global warming.
- Congress should set up a dedicated stream of funding for conservation adaptation and restoration in the global warming legislation. Congress should also provide adequate resources for the federal agencies charged with implementing the legislation. The legislation should also include appropriate resources for providing long-term budgetary stability.

Manage the Land in the Face of Global Warming

[illegible]

- Federal, state, and local agencies and managers should consider and take into account the impacts of global warming when planning and managing parks, preserving wildlife and other natural resources, and [illegible]

[illegible]

Land conservation efforts are currently underway in Maryland and Virginia. Chesapeake Bay stakeholders and the Chesapeake Bay program have supported these programs, and have called for greater funding and support. These programs include the Maryland Program for Open Space and the Virginia Land Conservation Foundation. Unfortunately, [illegible] to global warming is [illegible] and developing strategies for land conservation and habitat protection are in their infancy.

- Congress should:
  [illegible] dedicated funding for the conservation programs of the Farm Bill. Land conservation agencies and farm leaders in Maryland and Virginia should work together to develop a strategy for dedicated funds and other sources of funding for conservation and support open space.

[illegible]

- Maryland and Virginia should [illegible] approaches to assess and manage the impacts of global warming on land resources. Maryland and Virginia should also [illegible] the Bay Watershed on [illegible] conservation programs, science, research, and management, and [illegible] conservation [illegible] and [illegible] habitat, wetlands, and other resources.

Governments and Individuals Must Take Action Now

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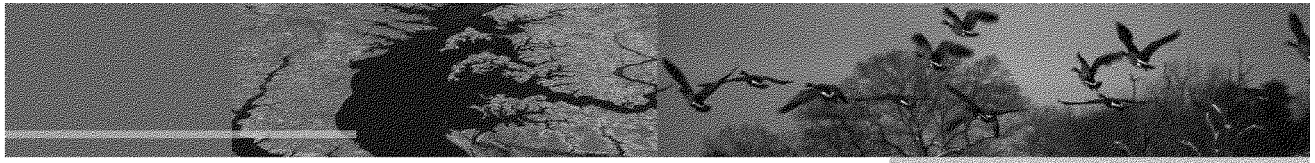


I. INTRODUCTION

The Chesapeake Bay is a Paradise for Hunters, Anglers, and Outdoor Enthusiasts

Hunting, fishing, and other outdoor traditions have been an important part of life in the Chesapeake Bay region for generations. Whether it is the thrill of reeling in a prized rockfish off Smith Point, spending a weekend with friends hunting canvasbacks on Maryland's Eastern Shore, or digging for clams on a sandy beach, the Chesapeake Bay's habitats provide incalculable value to the region and nation.

For waterfowlers, the Chesapeake Bay is a cherished destination. Each year, more than one million ducks, geese, and swans come to the bay for stopover and wintering habitat, congregating in the coastal wetlands of protected areas such as the Blackwater National Wildlife Refuge in Maryland and the Saxis Wildlife Management Area in Virginia. In 2001, close to 100,000 people hunted waterfowl in Maryland and Virginia combined, contributing $25.5 million to the regional economy.[1]

As home to more than a dozen species of game fish, the Chesapeake Bay is also a fishing paradise. In 2001, residents and visitors spent more than $700 million on saltwater recreational fishing in Maryland and Virginia, including the waters of the bay.[2] The Susquehanna Flats, Tangier Sound, Smith Point, and many other bay areas are year-round destinations for saltwater anglers pursuing prized game fish.

And millions of people flock to the Chesapeake Bay each year to go clamming, crabbing, build a sandcastle, cruise the waters, and enjoy a host of other outdoor recreational opportunities.

Preserving the Chesapeake Bay's treasured outdoor traditions for future generations will depend on how well we address growing conservation challenges, including global warming.

Trouble in Paradise: Multiple Threats to the Bay

Billions of dollars have been invested in the Chesapeake Bay watershed to restore and protect fish and wildlife habitat. The Clean Water Act, for example, has been a valuable tool for restricting wetland destruction and improving water quality. Federal farm programs such as Swampbuster, the Conservation Reserve Program, and the Wetlands Reserve Program have encouraged farmers to set aside wetlands and other important habitat for waterfowl.

The widespread decline of the bay led to the historic 1983 Chesapeake Bay Agreement in which Virginia, Maryland, Pennsylvania, the District of Columbia, and the U.S. Environmental Protection Agency established the Chesapeake Bay Program partnership to protect and restore the bay's ecosystem. Their initial focus was on toxic pollution, excess nutrient input to the bay, and declining seagrasses. Since then, the program has issued several plans with ambitious goals and timelines for bay restoration, and there have been important improvements in the health of the bay. The plan was revised most recently in 2000, when Delaware, New York, and West Virginia became more involved in the partnership.

Waterfowlers and anglers have helped expand protected areas through the duck stamp program, fishing licenses and other means. And they have been strong voices in support of responsible land use, wildlife, and fisheries management. Combined, these actions have helped bring populations of popular Chesapeake Bay fish and wildlife species—such as rockfish and Canada geese—back to healthy numbers.

But the bay still faces many challenges.[3] The majority of its waters are highly degraded due to excessive nutrients, chemical contaminants, and sedimentation. Critical habitats such as seagrass beds and tidal wetlands have shrunk under continuing pressure from development and pollution. Populations of many of the bay's fish and wildlife species are declining as a result. Hunters and anglers are seeing firsthand the fallout from these problems, whether it's lesions on rockfish or waterfowl that now stop elsewhere instead of the bay.

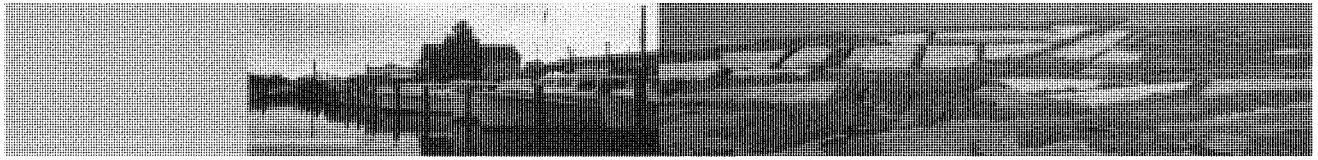
Today we also face extraordinary challenges brought on by human-caused global warming, primarily generated by the rapidly accelerating use of fossil fuels. Global warming is not a distant threat. It is causing major changes to our natural systems today: warmer air and water, rising sea levels, more extreme weather, and changing climates. As the evidence makes clear, these changes pose a great risk to the treasured outdoor traditions that have shaped the region for generations.

TOP: LEFT, LOGG; TOP RIGHT, INTERDICTION AND APPLICATION NETWORK; JOHN BRIGHT, USFWS

BOX 1.
Blackwater National Wildlife Refuge

Among the many treasured natural places along the Chesapeake Bay, the Blackwater National Wildlife Refuge is a crown jewel. Located on Maryland's Eastern Shore, the refuge is home to a diverse and abundant collection of fish and wildlife. Thousands of migrating ducks, geese, and swans use the refuge as stopover and wintering areas, making it popular for hunting waterfowl. At the same time, the wetlands help to control flooding and maintain water quality.

Sea-level rise is a major threat to the future of the Blackwater National Wildlife Refuge. Since the late 1930s, sea-level rise and overgrazing by nutria have contributed to a loss of one-third of the refuge's coastal marshes. As sea-level rise accelerates, the future of the refuge is in jeopardy. Saving such Blackwater and other coastal habitats will require diligent action both to reduce global warming pollution and to plan for habitat change brought on by sea-level rise.



II. GLOBAL WARMING THREATENS AN ALREADY BELEAGUERED CHESAPEAKE BAY

TABLE 1.
REPORT CARD FOR THE CHESAPEAKE BAY, 2000

Fisheries	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Habitat	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Pollution	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

The latest report card on the health of the bay, compiled by the Chesapeake Bay Foundation, provides a grim accounting (see Table 1).

Populations of shad, menhaden, blue crabs, native oysters, and hard clam species have declined dramatically due to pollution, habitat degradation, and other problems. Declines in wetland breeding habitats outside the region, as well as reductions in food sources in the Chesapeake Bay, have caused many duck populations in the region to decline. This is especially a problem among species that depend on submerged aquatic vegetation as a primary source of food, including northern pintails, redheads, and American wigeon.[4] In addition, marine diseases continue to plague the bay, and fish advisories warning of contamination from mercury and other toxic pollutants are routine.

To be sure, we already face daunting conservation challenges. Global warming will add significantly to those challenges.

Global Warming is Affecting the Chesapeake Bay Region

There is irrefutable evidence that human activities, particularly the burning of fossil fuels, have been causing excessive amounts of carbon dioxide and other greenhouse gases to build up in the atmosphere.[6] As a result, the Earth's average surface temperature has already increased by 1.7 degrees Fahrenheit, and scientists project that it will rise by another 2 to 11.5 degrees before the end of this century if we continue to depend so extensively on fossil fuels.[7] This warming is disrupting the planet's entire climate system. Average water temperatures are increasing, precipitation patterns are changing, and extreme weather events such as droughts, floods, storms, and heat waves are becoming more severe.[8] At the same time, the thermal expansion of the oceans combined with rapidly melting glaciers and ice fields are causing the average global sea level to rise at an accelerating rate.

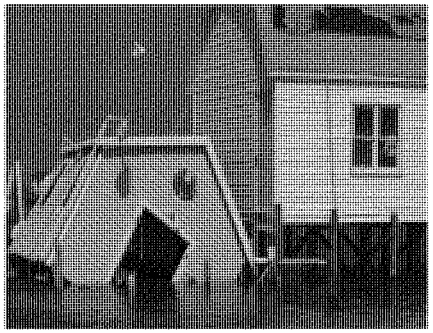
We can feel the effects of global warming in the Chesapeake Bay watershed. Average air temperatures in the region have increased by 1.4 degrees Fahrenheit along the coastal margins of the Chesapeake Bay through Maine over the past century, and much of the region has seen about a 10 percent increase in average precipitation, with greater precipitation extremes.[9] The period between the first and last dates with snow on the ground has decreased seven days over the past 50 years.[10] The average water temperatures in the bay also rose about 1.4 to 2 degrees Fahrenheit from the 1950s to 2000.[11]

At the same time, average sea levels in the Chesapeake Bay have been rising. Many places along the bay have seen a one-foot increase in relative sea-level rise over the 20th century, six inches due to global warming and another six inches due to naturally-subsiding coastal lands—a factor that places the Chesapeake Bay region at particular risk. Already, many of the bay's coastal marshes and small islands have been inundated. At least 13 islands in the bay have disappeared entirely, and many more are at risk of being lost soon.[12]

Failure to Combat Global Warming Means Even Greater Changes in the Decades to Come

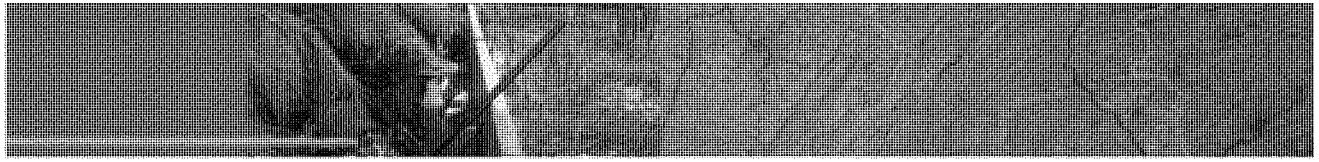
As global warming pollution continues, these trends will worsen. Air temperatures in the Chesapeake Bay region will continue to increase, as much as 4 to 14 degrees Fahrenheit by the end of the century.[13] Waters in the bay will also continue to warm, with direct implications for aquatic plants and animals.

Recent studies also point to a greater likelihood of increased precipitation in the Chesapeake Bay region. By the end of the 21st century, the region could see an 8 to 15 percent increase in average precipitation compared to 2000.[14] In particular, climate models suggest that winter and spring precipitation will increase.[15] Because the extent of summertime plankton blooms and stratification is partly determined by runoff into the bay during winter and spring, increases in precipitation during these seasons could be especially problematic.[16]



TOP: LEFT, NOAA; TOP RIGHT, UNI; RIGHT, VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

In addition, relative sea-level rise in the Chesapeake Bay region could reach 17 to 28 inches above 1990 levels by 2095.[17] This increase is significantly greater than the global average sea-level rise of 7 to 23 inches projected by the Intergovernmental Panel on Climate Change (IPCC)—again due to land subsidence.[18] If the melting of the Antarctic and Greenland ice sheets accelerates during the coming decades, as new studies suggest, sea-level rise in the Chesapeake Bay could be considerably greater.[19]



III. A TRIPLE THREAT TO WATERFOWL HUNTING

The Chesapeake Bay has long been one of the most important areas in North America for wintering waterfowl and has a tradition of excellent waterfowl hunting. The nation's largest collection of wooden duck decoys is housed at the Havre de Grace Decoy Museum, while the annual Waterfowl Festival in Easton attracts thousands of waterfowl enthusiasts from across the country.

Unfortunately, it has become clear that global warming poses a triple threat to waterfowl hunting in the Chesapeake Bay region. First, the breeding grounds for many of the bay's wintering ducks, the Prairie Pothole Region in the upper Great Plains, is expected to become much drier and produce fewer ducks because of global warming. Second, some migrating waterfowl are already stopping in ice-free areas farther north and west as winters become warmer, and the trend is expected to continue. Finally, waterfowl that do migrate all the way to Chesapeake Bay are likely to find a loss of shallow-water wintering habitat as sea levels increase.

With the impacts of global warming already affecting the bay, waterfowl hunters can't afford to wait to take actions that would slow the detrimental impacts of climate change. Quality days in the marshes and fields across the bay are already declining, jeopardizing the Chesapeake's long-term waterfowl heritage.

Declines in Prairie Pothole Wetlands

Global warming in regions far from the Chesapeake Bay will also affect the bay's wintering waterfowl populations. The Prairie Pothole Region of south-central Canada and the north-central United States, so-called for its abundance of small and shallow pothole-like wetlands, is the single most important breeding ground for North America's migratory ducks. About 50 percent of the nation's annual duck production is from the Prairie Potholes, which is especially important for mallards, gadwall, blue-winged teal, northern pintails, canvasbacks, and redheads. The majority of canvasbacks wintering in Chesapeake Bay are produced in the Prairie Potholes (see Box 2).

As the climate warms and evaporation and transpiration by plants increase, Prairie Pothole wetlands are expected to either dry up or remain wet for shorter periods, making them less suitable for duck breeding. Average March-to-May temperatures in the region increased in the latter half of the 20th century, and continued warming would be expected to raise evaporation rates and reduce soil moisture by 25 percent by the middle to the end of this century, particularly in summer months.[20] Models of future drought conditions in the region due to global warming indicate declines of up to 91 percent of Prairie Pothole wetlands by the 2080s, which could lead to a reduction of as much as 69 percent in the population of ducks breeding in the Prairie Potholes.[21]

Short-Stopping: Where Have All the Ducks Gone?

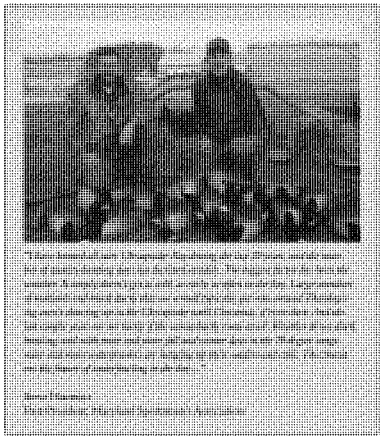
Milder winters are already hurting waterfowl hunting as waterfowl delay migration due to the later onset of fall, or stop short of their usual wintering grounds when they find suitable wintering areas farther north. Lakes and rivers throughout the northern hemisphere are now freezing an average of six days later than they did 100 years ago.[22] And in some areas, lakes that tended to freeze completely in the winter now often remain at least partially open. For example, from 1850-1949, Lake Champlain completely froze over 95 percent of the time. But, from 1950 to 1999 Lake Champlain froze over only 54 percent of the time. As global warming continues, lakes will increasingly freeze later or not at all some winters.

During mild winters, waterfowl do not need to migrate as far south or as early as usual because they can find open water much more readily in more northerly areas. There are many reported incidents of this so-called short-stopping. For example, in the unusually mild winter of 2005-2006, Canada geese were observed for the first time spending the winter as far north as Prince Edward Island, on the Atlantic coast north of Nova Scotia. Tundra swans have wintered on open rivers in Canada and canvasbacks are also short-stopping due to milder weather (see Box 2).

As this trend continues, waterfowl enthusiasts in the Chesapeake Bay and other places in the southern parts of the country can expect poorer hunting seasons. Delayed migration of waterfowl brought on by warming winters may force government officials to delay the opening of the annual waterfowl season. Even then, waterfowl hunters in the marshes will likely see fewer and fewer ducks.

Habitat Loss

Challenged by declining wetlands for breeding and short-stopping as winters become milder, waterfowl that do reach the Chesapeake Bay face a con-



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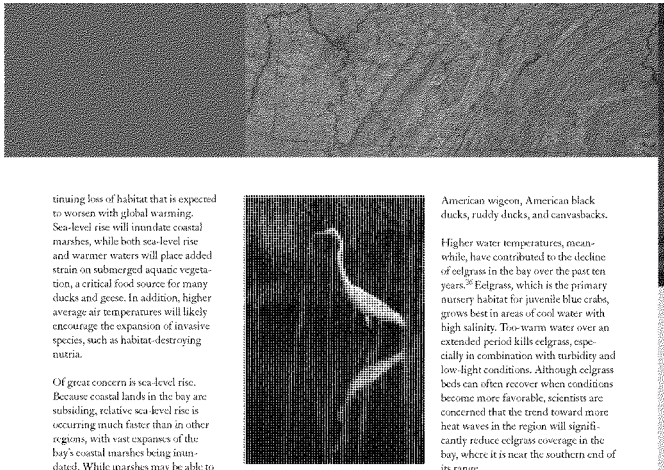

tinuing loss of habitat that is expected to worsen with global warming. Sea-level rise will inundate coastal marshes, while both sea-level rise and warmer waters will place added strain on submerged aquatic vegetation, a critical food source for many ducks and geese. In addition, higher average air temperatures will likely encourage the expansion of invasive species, such as habitat-destroying nutria.

Of great concern is sea-level rise. Because coastal lands in the bay are subsiding, relative sea-level rise is occurring much faster than in other regions, with vast expanses of the bay's coastal marshes being inundated. While marshes may be able to accommodate moderate changes in sea level through natural sedimentation and marsh accretion (the build-up of organic matter), studies have shown that the rates of sedimentation and accretion for most Chesapeake Bay marshes are failing to keep pace with the rate of sea-level rise.[23] This disparity is expected to worsen as the rate of sea-level rise accelerates with global warming.

Furthermore, as sea-level rise floods low-lying areas, the introduction of miles of seawalls, bulkheads, and other armoring of coastlines precludes the natural creation of new coastal habitat. With an 18-to-24-inch rise in relative sea level, well within the projections for the 21st century, it is not far-fetched to envision the bay being surrounded not by

beaches and marshes, but by bulkheads and seawalls.[24]

Sea-level rise also is expected to have a direct impact on the distribution and composition of seagrass by increasing the water depth and thereby reducing the sunlight that seagrass needs for photosynthesis.[25] Seagrasses, or submerged aquatic vegetation, are a critical resource that provide food and habitat for a wide range of bay species, including crabs, fish, and waterfowl. Seagrasses also protect shorelines from erosion, remove nutrients from the water, and trap sediments that cloud bay waters. Rapid sea-level rise would undermine the current efforts to restore seagrass beds throughout much of bay, which would have a significant impact on species that depend on the seagrasses for food, including redheads, northern pintails, American wigeon, American black ducks, ruddy ducks, and canvasbacks.

Higher water temperatures, meanwhile, have contributed to the decline of eelgrass in the bay over the past ten years.[26] Eelgrass, which is the primary nursery habitat for juvenile blue crabs, grows best in areas of cool water with high salinity. Too-warm water over an extended period kills eelgrass, especially in combination with turbidity and low-light conditions. Although eelgrass beds can often recover when conditions become more favorable, scientists are concerned that the trend toward more heat waves in the region will significantly reduce eelgrass coverage in the bay, where it is near the southern end of its range.

Furthermore, warmer conditions are likely to allow invasive species to become a greater presence in the bay area, potentially harming native species by outcompeting them for habitat and food. One invasive species that could benefit from warmer winters in the region is the South American nutria, a highly destructive rodent that was introduced into Maryland's Eastern Shore in 1943 to support the fur trade.[27] Foraging nutria have caused significant local damage to marshes in the region, including destroying more than 7,000 acres in Blackwater National Wildlife Refuge. The nutria has been limited in its northward range due to intolerance for harsh winter conditions. But as winters in the region become milder, conditions will be more favorable for nutria to move northward.[28]

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BOX 2.
Canvasbacks

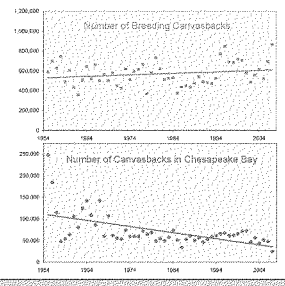
The largest of the diving ducks, the canvasback is popular among waterfowl hunters. While overall canvasback populations for the past 50 years have been stable, the number of wintering canvasbacks in the Chesapeake Bay has declined from a high of nearly a quarter million birds in the mid-20th century to an average of just over 30,000 birds in the last five years (see figure to the right).

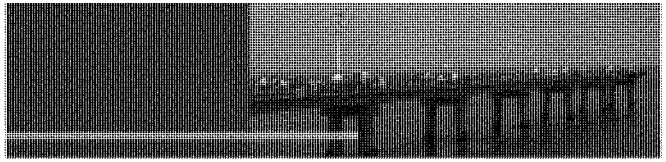
Long-term observations indicate that canvasbacks have virtually abandoned the bay due to a loss of submerged aquatic vegetation. The loss of this essential vegetation is associated with water degradation, including nutrient over-loading from runoff, which leads to algal blooms and less sunlight.

Short-stopping due to milder winters is also a factor in the decline of the canvasbacks, many of which migrate from their breeding ground in the Prairie Potholes through the Great Lakes to the Chesapeake Bay. In the spring of 2007, the number of breeding canvasbacks was the highest ever reported in the annual Waterfowl Breeding Population Survey.[27] But only six months earlier, a record-low 13,800 canvasbacks were observed in Chesapeake Bay in the January 2007 Mid-winter Waterfowl Survey.[28] The "missing" canvasbacks were observed in unusually high numbers in the Great Lakes, which remained largely unfrozen in the winter of 2006-7 due to the unusually mild and late winter.

As winters become even milder due to global warming, canvasbacks may have little reason to migrate to the bay and could winter primarily in the Great Lakes instead.

SURVEY OF CANVASBACK POPULATION LEVELS IN UPPER MIDWEST BREEDING GROUNDS AND CHESAPEAKE BAY WINTERING AREAS





IV. "GONE FISHING" OR FISHING GONE?

The Chesapeake Bay has been known historically for both its commercial fisheries and outstanding sport fishing. In recent decades, the bay's fishing reputation has been marred by declining catches and intermittent bans on rockfish, blue crabs, oysters, and other species. Contributing factors to these problems include over-fishing, excessive nutrients, sedimentation, disease, water pollution, loss of submerged aquatic vegetation, and shoreline development. Now, on top of these factors, global warming is having a profound effect on the entire Chesapeake Bay aquatic ecosystem by increasing water temperatures, raising sea levels, and changing freshwater inflow. Although the bay's complexity makes precise projections of future conditions challenging, it is certain that these changes will affect fish populations and fishing opportunities.

[illegible]

Rockfish

[illegible]

Warmer Water

Anglers are well aware of the sensitivity of fish to temperature and often refer to sea-surface temperature maps to determine where a particular species might be. As global warming increases air temperatures, bay water temperature will also rise. Assuming other habitat conditions are suitable, higher temperatures are expected to favor increasing populations of such warm-water species as brown shrimp, black drum, spotted seatrout, grouper, and southern flounder .[34]

On the other hand, increasing temperatures are a threat to such species as rockfish (sometimes called "striped bass"), Atlantic sturgeon, soft-shelled clams, and winter flounder, which thrive in relatively cool water. As temperatures increase, these species are stressed by both increased energy needs and lower oxygen supplies. When stressed, fish decline in overall health and become more susceptible to disease.

Marine Diseases Spreading

In marine ecosystems around the world, new diseases and more frequent epidemics have been causing mass mortality in important marine species, such as corals and marine mammals, with strong links to global warming.[32] Chesapeake Bay fisheries are not immune to this trend.

A new species of mycobacterium recently infected rockfish, and mycobacterial infections have increased in other bay fish species, including menhaden.[35] A wide variety of factors is likely responsible, including declining water quality, pollution, habitat degradation, and global warming.[24] Warmer water may enhance mycobacterial growth and infection, but it also stresses species that prefer cooler water, making them more vulnerable to infection.

Native oysters, once estimated at only about 1 percent of historic levels, have been devastated by the deadly oyster diseases MSX and Dermo. MSX appears to be less active and less infectious at lower temperatures. Dermo is also limited by colder conditions, and winter temperatures typically limit its range, but it had a rapid expansion of oyster infection and mortality northward up the Atlantic Coast from Delaware Bay during a period of especially warm winters starting in 1990.[15] With cold winters becoming rarer as the climate warms, MSX and Dermo are likely to continue to flourish as water warms earlier in the spring and stays warm later in the fall.

TABLE 2. POTENTIAL IMPACTS OF GLOBAL WARMING ON CHESAPEAKE BAY FISHERIES

[illegible] Potential loss of species distribution in the Chesapeake Bay

[illegible] Likely decline in species range or viability in the Chesapeake Bay

[illegible] Likely increase in species range or viability in the Chesapeake Bay

SPECIES	LIKELY TREND	CLIMATE CHANGE IMPACTS IN CHESAPEAKE BAY
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
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[illegible]

Dead Zones to Expand

Eutrophication is a major problem, if not the major problem, for fish in the Chesapeake Bay, and it is likely to be exacerbated by global warming. Eutrophication is caused by an increase in nutrients, including nitrogen and phosphorus, in coastal waters. This leads to excessive phytoplankton growth that contributes to a depletion of oxygen in affected waters. Large areas of oxygen-depleted water can lead to significant fish kills among coastal species, particularly smaller, schooling fish such as menhaden. In August 2005, a record dead zone covered more than 40 percent of the bay.

River flow, which carries nutrients from agricultural fields and other sources into the Chesapeake Bay, is a major factor in hypoxia (low oxygen) and anoxia (no oxygen) events.[36] Heavier precipitation flushes greater amounts of nutrients and other pollutants into the bay, contributing to eutrophication and oxygen depletion.[37] Heavy runoff also decreases water mixing as less dense fresher water rides over the top of the denser saltier water, inhibiting the mixing of water and inhibiting the replenishment of oxygen in deep waters.

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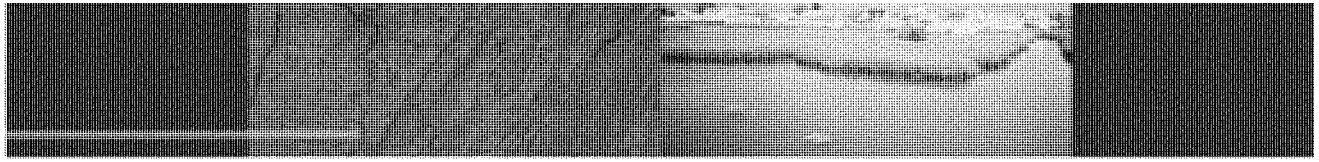

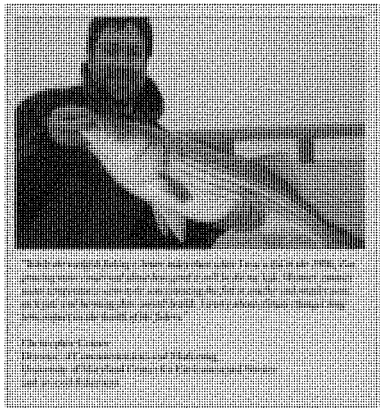

Water temperatures also affect oxygen levels because warm water holds less dissolved oxygen than cooler water does. For each degree Fahrenheit in temperature increase, the water's ability to dissolve oxygen decreases by about 1 percent.[38] Higher water temperatures also accelerate the bacterial decay of organic matter present in the water, thereby consuming oxygen and exacerbating hypoxia.[39]

Waters without oxygen are essentially uninhabitable for marine life. High water temperatures and resulting loss of oxygen were identified as the leading cause of major fish kills among 22 coastal states between 1980 and 1989.[40] Furthermore, higher average sea temperatures and eutrophication are considered to be a factor in the growing number and severity of harmful algal blooms, such as "red tides," "brown tides," and "mahogany tides," throughout the nation's coastal waters, including the Chesapeake Bay.[41]

The urgent battle against bay eutrophication will become more difficult as global warming continues. Although different models show varying results, there is agreement that precipitation will increase in late winter and early spring.[42] Increases in the spring flow of the Susquehanna River have been associated with increases in anoxia in the Chesapeake Bay during the summer.

Drowning our Fishing Heritage

Coastal wetlands of the Chesapeake Bay are already disappearing due to sea-level rise, and will continue to do so as global warming increases. While some new wetlands are likely to be created in low-lying upland coastal zones, efforts to minimize land loss and protect roads, buildings, and other structures will likely lead to more "armoring" of shorelines, precluding the development of new wetlands in these areas.

Unless major efforts are implemented to ensure the development of new wetlands as the sea level rises, the loss of coastal wetlands will have a significant impact on bay life. Tidal wetlands serve as filters of bay waters and stabilizers of shallow water and inter-tidal zones. Many game fish and other species depend on coastal marshes and seagrass beds for spawning, feeding, and protection. At risk from the loss of these important coastal habitats are rockfish, flounder, bluefish, menhaden, and other species. Wetland loss will also reduce essential habitat for important prey species, such as shrimp, crabs, and smaller fish, which would have ripple effects throughout the bay's food chain.

Furthermore, sea-level rise makes the coasts more vulnerable to erosion from storm surges and wave action. The depth of water in estuaries has a significant influence on wave action during storms—the deeper the water, the larger and more destructive the waves.[43] This is of a special concern because hurricanes and other storms will likely be stronger in the coming decades (see Box 4).

BOX 4.

Hurricanes – A Growing Menace

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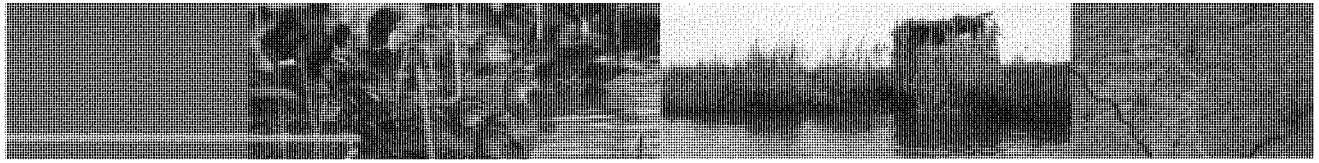

V. CHANGING THE FORECAST FOR THE CHESAPEAKE BAY: A PLAN OF ACTION

Even though the problems posed by global warming seem daunting, practical solutions are available. By reducing global warming pollution while taking steps to help wildlife cope with some of the inevitable changes, we can ensure that the Chesapeake Bay's treasured natural heritage and sporting legacy will endure.

Effectively managing the land in the face of global warming is a major challenge for the next decade and beyond. Across the Chesapeake Bay region, officials have recognized the importance of protecting wetlands, forests, and other natural habitats from encroaching urban development and better managing already-developed and agricultural lands. Sound land use is one of the primary goals of the Chesapeake 2000 Bay Agreement. However, failure to explicitly consider global warming as part of these efforts will make it much more difficult, if not impossible, to meet conservation goals.

The time for action is now, because many of the decisions we make today—from where and how we build our homes, businesses, and highways, to how much and what kinds of energy we use—will have a significant impact on the Chesapeake Bay and its fish and wildlife for decades to come.

Policy makers in Washington, along with the governments and citizens of Maryland and Virginia, can play a critical role in advancing meaningful solutions to change the forecast for the Chesapeake Bay. This section makes recommendations in seven broad areas to accomplish that.

1. Reduce Global Warming Pollution and Provide New Funding for Wildlife

To help fish and wildlife in the Chesapeake Bay, we need a two-pronged approach. First, we must curb global warming pollution, thereby limiting the magnitude of changes to the climate and ecosystems. Reducing global warming pollution at a rate of 2 percent per year from current levels will significantly improve the forecast for fish and wildlife (see Box 5). This will require action by the federal government, as well as states, localities, and individuals.

But, even if we successfully reduce global warming pollution, fish and wildlife in the bay will inevitably face some impacts of global warming. There will still be some warming over the next century from greenhouse gases that are already in the atmosphere and those that we will continue to emit while transitioning to new energy sources. New and enhanced restoration and adaptation strategies will be needed. To develop those effectively, fish and wildlife agencies must be given a permanent, stable, and new funding source.

For years, sportsmen have helped sustain fish and wildlife populations through the purchase of licenses and permits, as well as special excise taxes on hunting and fishing equipment. The U.S. Congress has provided some additional funding for state fish and wildlife agencies ($61 million in 2005), but it is far short of what is needed to sustain fish and wildlife populations affected by global warming.

Programs to reduce global warming pollution should be designed to provide funds to sustain wildlife habitat and populations during the period when global warming threatens these critical resources. The leading proposals in Congress for controlling global warming pollution create a new system of permits for major emitters, often referred to as a "cap-and-trade" system. Under such a proposal, the government would auction off annual permits that allow industry to emit a certain amount of carbon dioxide and other greenhouse gases. At the end of the year, each industrial source would be required to hold permits to cover its emissions for the year. As such a system is put in place, it is critical that a portion of proceeds from the auction of emission permits be set aside to fund conservation of fish and wildlife.

Such a cap-and-trade system for regulating global warming pollution can provide a double benefit for fish and wildlife. It will help reduce the impacts of global warming and it will provide new funding for resource managers to help fish and wildlife cope with those climate changes that are inevitable. In an added benefit for the Chesapeake Bay, many of the measures that reduce global warming pollution will also reduce nitrogen emissions that are ultimately deposited in the bay.

Dedicated conservation funding will be crucial to help states develop strategies for protecting fish and wildlife from global warming, integrate fish and wildlife adaptation strategies into existing resource management plans, and carry out conservation actions. Indeed this funding could help support many of the activities recommended in this report.

Federal actions:

- The U.S. Congress and the administration should place mandatory limits on the nation's global warming pollution to ensure we meet the necessary target of 80 percent reduction by 2050.
- The U.S. Congress and the administration should pass a nationwide

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BOX 5.

Reducing the Threat from Warming

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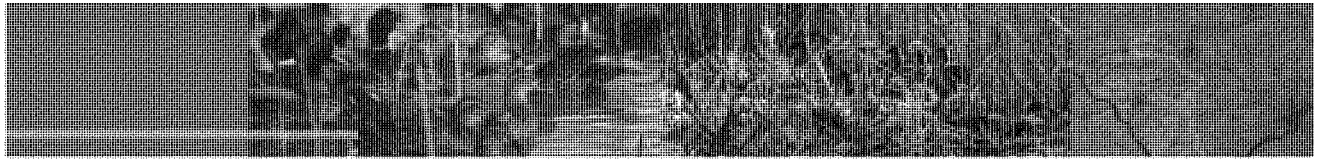


cap-and-trade bill to reduce global warming pollution, with roughly 10 percent of the revenue (from an auction of 100 percent of the permits) allocated for fish and wildlife conservation. The funding should supplement, not supplant, existing budgets for natural resource management, recognizing the new threat to fish and wildlife posed by global warming.

Maryland has taken some important steps to address global warming pollution. It joined the northeastern states' Regional-Greenhouse Gas Initiative, with a commitment to reduce carbon dioxide emissions from the state's utility companies by about 10 percent from current levels by 2019. It passed a renewable energy standard, which requires electric utilities to generate 7.5 percent of their electricity from renewable sources like solar, wind, and biomass by 2019. Recently, Maryland adopted a requirement to reduce carbon dioxide emissions from new cars sold in the state, and adopted more stringent efficiency standards for new appliances.[35] While much progress has been made in Maryland, more needs to be done. Virginia lawmakers have yet to act.

State Actions

- Maryland and Virginia should adopt a stringent carbon dioxide reduction goal of 2 percent per year, or 20 percent per decade, to achieve the necessary 80 percent reduction target by 2050.
- Maryland should strengthen its renewable energy standard to require utilities to generate at least 20 percent of electricity from renewable sources by 2020. Virginia should adopt a similar standard.

BOTTOM LEFT AND TOP RIGHT: NOAA

- Maryland should adopt more stringent building codes for government-owned buildings to require all new and renovated buildings to be carbon neutral by 2030. Virginia should adopt a similar standard.
- Virginia should adopt a "clean cars" bill and join the 10-state Regional Greenhouse Gas Initiative to work with neighboring states to achieve reduction in carbon dioxide emissions from power plants.

2. Expand State Wildlife Action Plans to Address Global Warming

In 2000, the U.S. Congress charged each state and territory with developing a wildlife conservation strategy. These Wildlife Action Plans identify at-risk species and habitats and outline the actions necessary to protect them, ultimately leading to cost-effective, proactive conservation strategies. To date, few of the plans include specific strategies to help wildlife cope with climate change.

Congress provided funding for creating and implementing these plans through the State and Tribal Wildlife Grants Program. Funds appropriated under this program are allocated according to a formula based on each state's size and human population. The average grant in 2007 was just over $1 million.

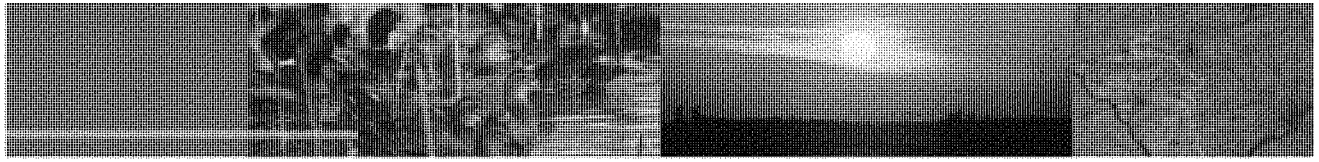
The Virginia Wildlife Action Plan mentions global warming as a threat to wildlife. Specifically, the plan lists the Blue Ridge Mountains and the biologically diverse Northern Ridge and Valley regions as particularly susceptible to change brought on by climate change. Several rare species and habitat types would likely be lost, including high-elevation forests, home to the endangered Carolina Northern Flying Squirrel. The current Virginia plan calls for more research, but does not include specific conservation actions that address global warming.

The Maryland Wildlife Action Plan, formally known as the Maryland Wildlife Diversity Conservation Plan, lists global warming and sea-level rise as statewide threats to wildlife. In particular, sea-level rise has contributed to the decline of the extremely rare type of floodplain forest, called a sea-level fen; the plan calls for restoring these wetlands by reintroducing northern conifers to the landscape and protecting them from ditching, draining, and water withdrawal. The Maryland plan also identifies sea-level rise as a threat to several types of coastal habitats: beaches, dunes, mudflats, and coastal plain freshwater streams. The plan calls for conserving these habitats by protecting and restoring riparian buffers, improving storm-water management systems, developing shoreline erosion control practices, and restoring native dune vegetation.

Maryland has taken an important first step to better account for global warming in its wildlife action plan. In April 2007, Governor O'Malley created the Governor's Climate Change Commission, charged with developing a strategy to reduce the sources and impacts of global warming. The Adaptation and Response Working Group of the Commission is developing state-based adaptation measures, with an initial focus on sea-level rise. Maryland could be one of the first states in the nation to develop a state-based adaptation plan.

State actions:

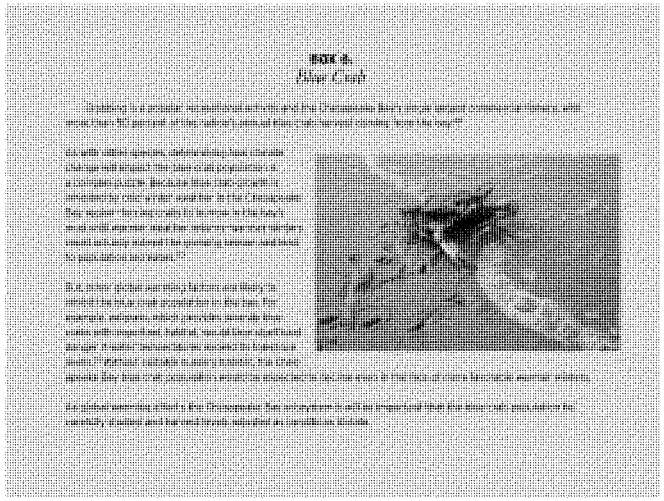
- In Maryland, continue efforts through the Governor's Climate Change Commission to develop a wildlife adaptation strategy that identifies fish, wildlife, and habitats threatened by climate change and outlines actions to protect them.



- In Virginia, develop a wildlife adaptation strategy that identifies fish, wildlife, and habitats threatened by climate change and outlines actions to protect them.
- In both states, incorporate adaptation measures related to climate change in the State Wildlife Action Plan.

3. Expand State-Based Funding for Maryland and Virginia Conservation Activities

Despite more than three decades of conservation and restoration activities, the Chesapeake Bay ecosystem is still stressed due to pollution, over-fishing, and coastal development. Moving ahead, global warming could significantly alter the bay's habitats, further disrupting its ability to support the fish and wildlife for which it is best known.



Reducing environmental stressors like nutrient overload, habitat loss, and fragmentation will make the system healthier and help wildlife survive the impacts of global warming. At the same time, new efforts are required to specifically address the habitat changes that global warming is likely to bring. These new activities will require new funding.

Conservation activities in both Maryland and Virginia are supported by a combination of special revenues—mostly from the sale of hunting and fishing licenses and taxes on sales of watercraft and equipment used in hunting and fishing—state general fund appropriations, and federal support. However, the funds available to the Maryland and Virginia agencies that handle conservation, fisheries, environment, and planning are insufficient to meet the current conservation challenges, much less the new challenges posed by global warming.

Furthermore agencies in both states face budgetary uncertainty from year to year. It is not uncommon that the special revenues supposedly dedicated for fish and wildlife conservation are redirected to other unrelated efforts. In Maryland, for example, funds dedicated for land acquisition in Program Open Space have often been redirected to other uses, hampering the effectiveness of the program. Such funding uncertainty will constrain agencies from pursuing new programs to address global warming.

Finally, the states should provide more accountability for their conservation spending to assure the public that such spending is effective. To that end, Maryland has recently began the BayStat initiative to track Chesapeake Bay restoration activities.[56] BayStat will help ensure that existing and new funding is well spent.

State actions:

- Legislatures in Virginia and Maryland should ensure that conservation agencies receive adequate, dedicated funding each year to meet existing conservation goals and to address the new challenge of global warming. The legislatures also should reduce reliance on the annual appropriations process and provide more long-term budgeting certainty.

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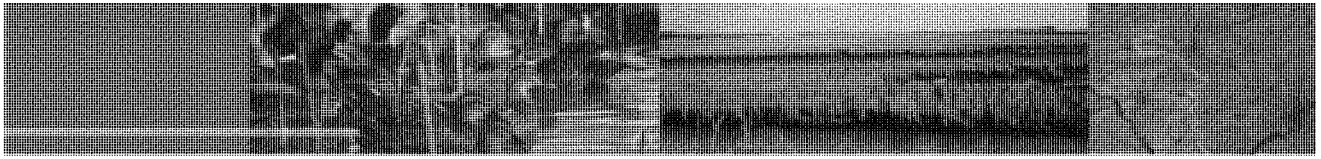

4. Adapt Waterfowl and Fish Management Practices

Waterfowl and fish migration patterns are shifting, and populations are changing in response to global warming, affecting which species frequent the Chesapeake Bay and when they are present. Indeed, global warming will have broad, interconnected impacts on entire marine ecosystems. Effective management will mean addressing the health of the habitat as a whole, rather than one species at a time. Yet, most fisheries management plans focus on single-species management and do not consider the inter-related impacts of climate change. An ecosystem management approach would be more effective and allow for better consideration of long-term changes such as those brought on by global warming.

If we fail to address global warming, shifts in waterfowl and fish migration patterns and declines in some species may also force resource managers to consider making adjustments to hunting and fishing seasons to ensure the long-term viability of species. The management approach will need to take into consideration year-to-year conditions as well as longer-term climate trends. For example, the delayed migration of waterfowl due to warming winters may force government officials to delay the opening of the annual waterfowl season.

State and Regional Actions:

- The Atlantic States Marine Fisheries Commission, the Mid-Atlantic Fisheries Management Council, the Virginia Marine Resources Commission, the Maryland Fisheries Service, and the Chesapeake Bay Program should move towards an ecosystem approach for managing fisheries in Chesapeake Bay. State and regional marine fisheries management plans should consider how climate change will affect fisheries.
- As species populations shift in response to global warming, fisheries managers should consider adjusting fishing regulations.
- The delayed migration of waterfowl due to warming winters may force government officials to delay the opening of the annual waterfowl hunting season.

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5. Discourage Extensive Coastal Development and Armoring of Shorelines

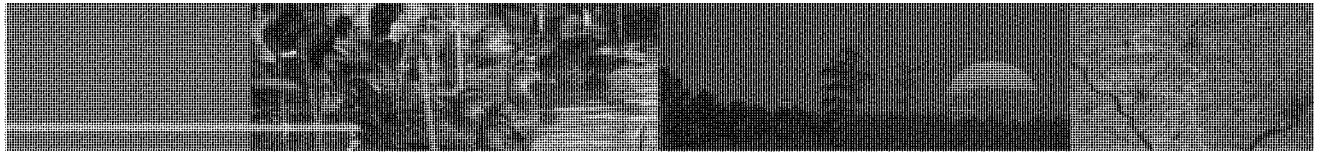
Sea-level rise should be a major consideration in the region's coastal development plans. Maryland has taken an important first step by establishing a state-wide Sea-level Rise Response Strategy, which has laid out a number of recommended actions.[57] To be successful, however, actions should be coordinated throughout the region.

The best ways to improve the ability of our coasts to withstand sea-level rise are to enhance the natural defenses provided by wetlands, barrier islands, and reefs; support the natural replenishment of sediments from rivers and beaches; and protect inland buffers to enable habitats to migrate. Whenever possible, resource managers and land-use planners should steer away from structural approaches such as seawalls and bulkheads for coastal protection. Coastal armoring hinders the ability of habitats to migrate inland as sea levels rise, preventing coastal wetlands from replenishing themselves through sediment buildup.

In addition, the region should discourage development in vulnerable areas. For example, both Maryland and Virginia currently designate that new development can not take place within a 100-foot buffer surrounding ecologically critical areas. This size buffer may not be sufficient as erosion and inundation rates accelerate due to sea-level rise, threatening habitats farther inland.[58]

Federal Actions:

- The U.S. Congress should reauthorize the Coastal Zone Management Act to require relevant state agencies to consider sea-level rise in coastal management plans to qualify for federal funding; prohibit federal subsidization of infrastructure development and coastal armoring in ecologically sensitive areas; and encourage public and private land acquisition of coastal habitats and upland buffers.
- The Federal Emergency Management Agency should remap potential hazard areas in coastal zones to reflect anticipated sea-level rise, taking into account potential storm surge impacts, and establish policies to reduce or eliminate federal flood insurance for new construction and rebuilding in high-risk areas.

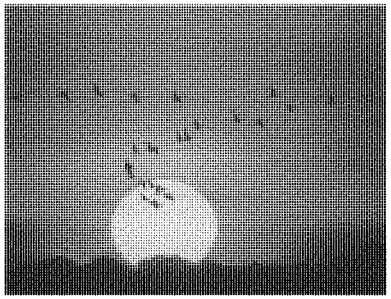


- The U.S. Congress should expand the Coastal Barrier Resources system to discourage new development in areas needed to buffer natural resources and existing development from sea-level rise. Such areas should be denied federal subsidies such as federal flood insurance, disaster relief, and loans for sewer, water, and highway construction.

State and Local Actions:

- Maryland and Virginia should enact new legislation requiring local governments to consider sea-level rise when amending their plans for coastal land use, open space, wetland protection policies, and other relevant activities.

- The Virginia Marine Resources Commission and the Maryland Department of Natural Resources in conjunction with the Maryland Department of the Environment should develop state tidal wetlands conservation and restoration plans that promote designation of wetland migration corridors and remove and discourage use of hard shoreline erosion structures in coastal marsh environments.



- The Maryland Department of Natural Resources should expand Maryland's Critical Area buffer designation and the Virginia Department of Conservation and Recreation should expand Virginia's Resources Protection Area buffer designations beyond the current 100-foot requirement to accommodate impacts of sea-level rise. States should also expand enforcement of current regulations and prevent any attempts to weaken these provisions in relevant legislation.

- State and local agencies should establish policies such as rolling easements or mandatory setbacks to discourage new development in vulnerable coastal areas.

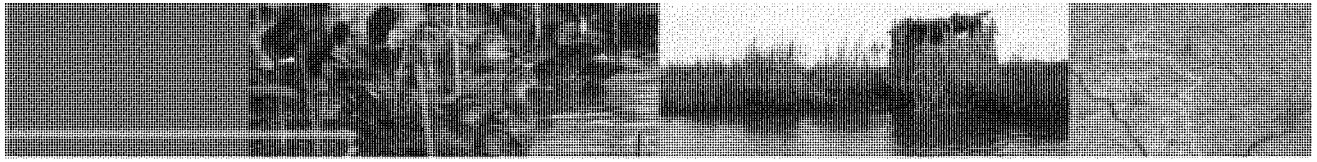
6. Account for Global Warming in Land Conservation and Habitat Protection Efforts

Numerous land conservation efforts are currently underway to restore and protect the Chesapeake Bay's habitats and the species they support. Bay-protection efforts have included limiting suburban sprawl, reflecting the fact that such development contributes to habitat fragmentation and destruction, air pollution, and water quality degradation. Many of these efforts will also make the region's coastal wetlands and other natural habitats more resistant to the effects of global warming. For example, habitat restoration and de-fragmentation along with open-space protection will allow wildlife to move more easily to new locations as climate shifts push them out of their current homes.

But it is also critically important for decision makers to explicitly account for global warming as they develop strategies for land conservation, habitat protection, and restoration. For example, while both Maryland and Virginia have a number of state-based land conservation programs—including Maryland's Program Open Space, the Virginia Land Conservation Foundation, and the Virginia Outdoors Foundation—neither state currently considers the impacts of global warming when assessing ecologically critical habitats for possible acquisition. Nor do the states' current land-use planning measures adequately consider the longer-term threats from global warming in their habitat-protection requirements. Maryland's Green Infrastructure criteria are a step in the right direction, but future revisions will need to consider global warming explicitly.

Agricultural lands play an important role in providing habitat for some waterfowl species, such as mallards and Canada geese. Accordingly, sportsmen and women have worked closely with the agricultural community, helping pass initiatives in the federal Farm Bill that provide incentives for wetlands and associated upland habitat conservation (such as the Wetland Reserve Program and the Conservation Reserve Program). Ensuring that these habitats are available is even more important as the region continues to face added pressures on coastal wetlands, seagrass beds, and other natural habitats due to global warming. However, the Farm Bill conservation programs are currently under-funded. In Fiscal Year 2004, for example, three out of every four applications to participate in Farm Bill conservation programs administered by the Natural Resources Conservation Service were rejected due to lack of funds.[39] At the same time, the conservation rates paid to land owners are not always keeping pace with increasing land values.

LUTTRECK, TOM-REGIT-USFWS



Federal Actions:

- The U.S. Congress should significantly expand funding for the conservation provisions of the Farm Bill, including the Conservation Reserve Program, the Wetlands Reserve Program, the Conservation Security Program, the Grasslands Reserve Program, and the Wildlife Habitat Incentives Program. These provisions should include greater incentives for maintaining coastal and riparian buffers in response to increased runoff and sea-level rise.

State Actions:

- Land conservation agencies and foundations in Maryland and Virginia should develop improved criteria for identifying ecologically critical lands, in particular considering how sea-level rise and other climate changes will hurt habitats, and seek opportunities to acquire or better manage these lands.

- Maryland and Virginia should ensure that the Farm Bill conservation programs preserve existing commitments and encourage new enrollments. This may involve adjusting the rates paid to land owners or finding efficient ways to restore relatively small parcels, such as buffers along streams.

7. Redouble Efforts to Manage Storm-water Runoff into the Chesapeake Bay

As the region faces greater extremes in precipitation events, including heavier rainfall and the possibility of more-intense coastal storms, improving storm-water management will be critical to meeting important goals to reduce eutrophication in the Chesapeake Bay. This is particularly important as the region considers denser development and redevelopment projects in the interest of smart growth.

Significant efforts are being made in the region to improve storm-water and wastewater management, including new legislation in Maryland to develop more effective storm-water environmental site design. The state has also identified storm-water retrofits as a priority for funding under its Green Fund proposal. Similar efforts are warranted in Virginia, where current funding for the Virginia Water Quality Improvement Fund is inadequate.

In both states and across the region, however, storm-water managers must seriously consider the likelihood of heavier precipitation and more runoff problems due to global warming. For both new developments and redevelopment projects, it is critical to incorporate non-structural, preventive measures employed through land-use planning and educational programs, in addition to the structural fixes, such as water treatment systems for large point sources, that have been emphasized in the past. Promoting more flexible strategies and moving development away from sensitive areas can also help handle precipitation extremes. In addition, reducing runoff flows over impervious surfaces such as roads and parking lots can help moderate high water temperatures in tidal creeks and marshes, a problem that is likely to be exacerbated by global warming.[50]

The region must also establish runoff-reduction goals that account for greater extremes than are reflected in historic trends. For example, even where technological solutions to storm-water management are warranted (e.g., retrofitting culverts and storm drains), it will be prudent to consider expanding the capacity today rather than being faced with having to re-invest in further

retrofits in the coming decades. Several actions at the federal and state levels will help improve storm-water management in the region to more effectively deal with the added pressures from global warming.

Federal Actions:

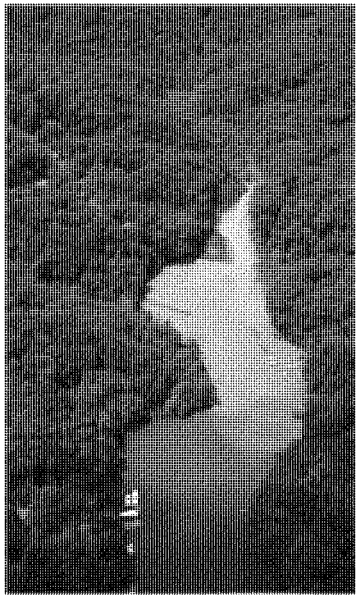
- The U.S. Environmental Protection Agency should revise its storm-water management rules under the Clean Water Act to discourage construction in or near coastal and stream riparian buffers, wetlands, and other sensitive areas.

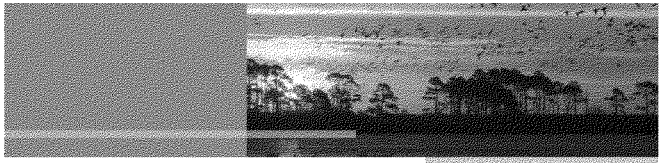
State and Local Actions:

- Virginia should develop a dedicated funding source for sewage and wastewater treatment upgrades and provide sufficient funding to the Virginia Water Quality Improvement Fund.

- Both Virginia and Maryland (through its Green Fund) should increase support of non-structural approaches to storm-water management (i.e., preventive measures incorporated in land-use and development planning rather than technological fixes of point-source pollution) and require consideration of greater extremes in precipitation events due to global warming.

- Both Virginia and Maryland should consider stricter storm-water permits to steer development away from coastal and stream buffer areas, wetlands, and other sensitive lands.





VI. CONCLUSION

Global warming poses a significant threat to the fish and wildlife of the Chesapeake Bay. Left unchecked, global warming will lead to rising sea levels and coastal inundation and an increase in marine diseases and harmful algal blooms. It will place the region's people and wildlife at increasing risk from catastrophic storms and other extreme events. Warmer air and water, both locally and across the continent, will alter the composition of fish and wildlife species that make their home in the bay region. These effects will fall on top of the many other problems, such as eutrophication, that continue to plague the bay.

But it is not too late to act. It will take foresight, the right investments, and determination to reduce the risks rather than wait for the consequences. Hunters, anglers, and all those who cherish the beauty and recreational opportunities offered by the Chesapeake Bay can make a difference by letting elected officials at the federal, state, and local levels know that the time for action is now. And, we can all make changes in our day-to-day lives to reduce our contributions to global warming pollution (see Box 7) and to manage properties we own to minimize the negative impacts on fish and wildlife.

By taking action now to both restore the bay and reduce global greenhouse gas emissions, we can change the forecast for the Chesapeake Bay and ensure that its economic opportunities, ecological benefits, and outdoor traditions will endure for generations to come.

BOX 7.

What Can You Do to Reduce Global Warming Pollution?

Individuals can make an important difference in reducing global warming pollution by changing how we use energy in our daily activities. There are many things you can do:

- Reduce energy consumption in your home by purchasing more energy-efficient lighting, such as compact fluorescent bulbs, and appliances with high-efficiency Energy Star ratings.
- When purchasing a new car or truck, buy the most fuel-efficient model that suits your needs.
- Install a programmable thermostat and set it warmer in the summer and cooler in the winter.
- Seek ways to use electricity generated from renewable sources.
- Make sure your boat motor is tuned up.
- Keep your vehicle's tires properly inflated.[50]
- Work in your local community to promote energy efficiency, recycle waste, plant trees, plan smart growth, or reduce traffic congestion.

TOP LEFT, USFWS

ENDNOTES

[1] U.S. Fish & Wildlife Service (FWS), *2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Maryland* (Washington, D.C.: U.S. Department of the Interior, Revised March 2003); FWS, *2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Virginia* (Washington, D.C.: U.S. Department of the Interior, Revised March 2003).

[2] Ibid.

[3] Chesapeake Bay Program, *Chesapeake Bay 2006 Health & Restoration Assessment, Part One: Ecosystem Health* (Annapolis, MD: Chesapeake Bay Program, 2007).

[4] A. Fisher, et al., *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change: Mid-Atlantic Foundations, Chapter 7: Coastal Zones* (University Park, PA: Pennsylvania State University, 2000).

[5] Chesapeake Bay Foundation, *2006 State of the Bay* (Annapolis, MD: Chesapeake Bay Foundation, 2006).

[6] Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: The Physical Science Basis, Summary for Policymakers* (Geneva: IPCC Secretariat, 2007a).

[7] Ibid.

[8] K.E. Trenberth, et al., "The Changing Character of Precipitation." *Bulletin of the American Meteorological Society* 84 (2003): 1205-1217; D.R. Easterling, et al., "Climate Extremes: Observations, Modeling, and Impacts." *Science* 289 (2000): 2068-74.

[9] K. Hayhoe, et al., "Past and Future Changes in Climate and Hydrological Indicators in the US Northeast." *Climate Dynamics* 28 (2007): 381-407; P.Y. Groisman, et al., "Contemporary Changes of the Hydrological Cycle over the Contiguous United States: Trends Derived from In Situ Observations." *J. of Hydrometeorology* 5 (2004): 64-84.

[10] Hayhoe et al., 2007.

[11] E. L. Preston. "Observed Winter Warming of the Chesapeake Bay Estuary (1949-2002): Implications for Ecosystem Management." *Environmental Management* 34 (2004): 125-139; H. M. Austin, "Decadal Oscillations and Regime Shifts, a Characterization of the Chesapeake Bay Marine Climate." *American Fisheries Society Symposium 32* (2002): 155-170.

[12] Environmental Protection Agency (EPA), "Climate Change, Wildlife, and Wildlands Case Study: Chesapeake Bay and Assateague Island." Available at: http://www.epa.gov/climatechange/wycd/downloads/CS_Ches.pdf (accessed September 17, 2007).

[13] R.G. Najjar, et al., "The Potential Impacts of Climate Change on the Mid-Atlantic Coastal Region." *Climate Research* 14 (2000): 219-33.

[14] Hayhoe et al., 2007.

[15] Najjar, Patterson, and Graham, 2007 (in preparation).

[16] W.M. Kemp, et al., "Eutrophication of Chesapeake Bay: Historical Trends and Ecological Interactions." *Marine Ecology Progress Series* 303 (2005): 1-29.

[17] R.G. Najjar, et al., 2000; S.Y. Wu, R.G. Najjar, and J. Siewert, "Sea-Level Rise Impacts: Potential Impacts of Sea-level Rise on the Mid- and Upper-Atlantic Region of the United States." (2007, submitted).

[18] IPCC, 2007a.

[19] J.L. Chen, C.R. Wilson, and B.D. Tapley, "Satellite Gravity Measurements Confirm Accelerated Melting of Greenland Ice Sheet." *Science* 313 (2006): 1958-60; B.L. Otto-Bliesner, et al., "Simulating Arctic Climate Warmth and Icefield Retreat in the Last Interglaciation." *Science* 311 (2006): 1747-50; J.T. Overpeck, et al., "Paleoclimatic Evidence for Future Ice-sheet Instability and Rapid Sea-level Rise." *Science* 311(2006): 1747-50; E. Rignot and P. Kanagaratnam, "Changes in the Velocity Structure of the Greenland Ice Sheet." *Science* 311 (2006): 986-90.

[20] M.G. Anderson and L.G. Sorenson, "Global Climate Change and Waterfowl: Adaptation in the Face of Uncertainty." *Transactions of the 66th North American Wildlife and Natural Resources Conference* (Washington, DC: Wildlife Management Institute, 2001): 306-319.

[21] L.G. Sorenson, et al., "Potential Effects of Global Warming on Waterfowl Populations Breeding in the Northern Great Plains." *Climatic Change* 40 (1998): 343-69.

[22] J.J. Magnuson, et al., "Ice Cover Phenologies of Lakes and Rivers in the Northern Hemisphere and Climate Warming." *Science* 289 (2000): 1743-1746.

[23] R.M. Erwin, et al., "Surface Elevation Dynamics in Vegetated Spartina Marshes Versus Unvegetated Tidal Ponds Along the Mid-Atlantic Coast, USA, With Implications to Waterbirds." *Estuaries and Coasts* 29 (2006): 96-106.

[24] IPCC, 2007a.

[25] F.T. Short and S. Wyllie-Echeverria, "Global Seagrass Declines and Effect of Climate Change," in C.R.C. Sheppard, ed., *Seas at the Millennium: An Environmental Evaluation, Vol. III* (Amsterdam: Pergamon, Elsevier, 2000): 10-11.

[26] K. Blankenship, "Underwater Grasses at the Tipping Point?" *Bay Journal* (Baltimore, MD: Alliance for the Chesapeake Bay, 2006).

[27] K. Wilkins, et al., *July 11, 2007 Administrative Report. Trends in Duck Breeding Populations. 1955-2007.* (Washington, D.C.: U.S. Fish and Wildlife Service, 2007).

[28] Maryland Department of Natural Resources, "Midwinter Waterfowl Survey Records Historic Low for Canvasbacks." Available at: http://www.dnr.state.md.us/dnrnews/pressrelease2007/051507.html (accessed September 10, 2007).

[29] Chesapeake Bay Nutria Working Group, "Nutria (Myocastor coypus) in the Chesapeake Bay: A Draft Bay-Wide Management Plan." Available at: www.chesapeakebay.net/pubs/calendar/NISW_12-10-03_Report_5_5129.pdf (accessed September 10, 2007).

[30] J.C. Stevenson, M.S. Kearney, and E.W. Koch, "Impacts of Sea Level Rise on Tidal Wetlands and Shallow Water Habitats: A Case Study from Chesapeake Bay." In N. A. McGinn, ed., *Fisheries in a Changing Climate* (Bethesda, MD: American Fisheries Society, 2002): 23-36.

[31] Fisher, et al., 2000.

[32] C.D. Harvell, et al., "Emerging Marine Diseases—Climate Links and Anthropogenic Factors." *Science* 285 (1999): 1505-10.

[33] R.A. Heckert, et al., "Detection of a New Mycobacterium Species in Wild Striped Bass in the Chesapeake Bay." *Clinical Microbiology* 39 (2001): 710-5; M.W. Rhodes, et al., "A Unique Mycobacterium Species Isolated From an Epizootic of Striped Bass (*Morone saxatilis*)." *Emerging Infectious Diseases* 7 (2001): 896-9; A.S. Kane, et al., "Mycobacteria as Environmental Pathogens in Chesapeake Bay Fish Species." *Emerging Infectious Diseases* 13 (2007): Available at: http://www.cdc.gov/EID/content/13/2/329.htm.

[54] J.O. Falkinham, et al., "Natural Ecology and Survival in Water of Mycobacteria of Potential Public Health Significance." In: J. Bartram, et al., editors. *Pathogenic Mycobacteria in Water: a Guide to Public Health Consequences, Monitoring and Management*. (London: IWA Publishing, 2004): 15–23.
[55] J.W. Ewart and S.E. Ford. *Northeast Regional Aquaculture Center Fact Sheet No. 200* (1993); T. Cook, et al., "The Relationship Between Increasing Sea-surface Temperature and the Northward Spread of *Perkinsus marinus* (Dermo) Disease Epizootics in Oysters." *Estuarine, Coastal and Shelf Science* 46 (1998): 587–597.
[56] J.D. Hagy, et al., "Hypoxia in Chesapeake Bay, 1950–2001: Long-term Change in Relation to Nutrient Loading and River Flow." *Estuaries* 27 (2004): 634–658.
[57] R.W. Howarth, et al., "The influence of climate on average nitrogen export from large watersheds in the Northeastern United States." *Biogeochemistry* 79 (2006): 163–186.
[58] Najjar, et al., 2000.
[59] J.C. Varekamp, et al., "The Paleo-environmental History of Long Island Sound as Traced by Organic Carbon, Biogenic Silica and Stable Isotope/Trace Element Studies in Sediment Cores." *Proceedings of the 6th Biennial Long Island Sound Meeting, Groton, CT, October 2004*: 109-113.
[60] A.J. Lowe, et al., *Fish Kills in Coastal Waters: 1980-1989* (Rockville, MD: National Ocean Service, NOAA, 1991).
[61] Harvell, et al., 1999.
[62] Harbison, et al. 2007; Najjar, Patterson, and Graham, 2007 (in preparation).
[63] J.H. Uphoff, Jr., "Predator-prey Analysis of Striped Bass and Atlantic Menhaden in Upper Chesapeake Bay." *Fisheries Management and Ecology* 1 (2003): 313–322.
[64] M.S. Kearney, "The Potential for Significant Impacts on Chesapeake Bay," *Scientific Symposium Presentation Abstracts, Washington Summit on Climate Stabilization, September 18-21, 2006* (Washington, D.C.: Climate Institute, 2006).
[65] K. Emanuel, "Increasing Destructiveness of Tropical Cyclones Over the Past 30 Years," *Nature*. 436 (2005): 686-688; Webster, et al., "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment," *Science* 309 (2005): 1844-1846.
[66] J.D. Andrews, "Effects of Tropical Storm Agnes on Epifaunal Invertebrates in Virginia Estuaries." *Chesapeake Science* 14 (1973): 223-234.
[67] U.S. Geological Survey (USGS), "A Summary Report of Sediment Processes in Chesapeake Bay and Watershed," *USGS Water Resources Investigations Report 01-4123* (New Cumberland, Pennsylvania: USGS, 2003 draft). Available at: http://www.chesapeakebay.net/temporary/usc/sedwg/final_draft_sed_rpt_7-3-03.pdf (accessed September 10, 2007).
[68] Kearney, 2006.
[69] Maryland Department of Natural Resources, "Blue Crab." Available at: http://www.dnr.state.md.us/fisheries/education/crab/bluecrabfacts.html (accessed September 10, 2007).
[70] G. Raymond, et al., "The potential impacts of climate change on the mid-Atlantic coastal region." *Climate Research* 14 (2000): 219–233.
[71] Maryland Sea Grant, "Global Warming and the Bay," *Chesapeake Quarterly Online* 5 (2006).
[72] IPCC, *Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability: Summary for Policymakers* (Geneva: IPCC Secretariat, 2007b).
[73] M. Meinshausen, "On the Risk of Overshooting 2°C." Presented at a scientific symposium on "Avoiding Dangerous Climate Change," (Exeter: Met-Office, 2005).
[74] IPCC, *Climate Change 2007: Mitigation of Climate Change: Summary for Policymakers* (Geneva: IPCC Secretariat, 2007c).
[75] Environment Maryland, "Action by States Would Lead to Major Reduction in Global Warming Pollution," *Global Warming Campaign News 3/21/2007*. Available at: http://www.environmentmaryland.org/newsroom/global-warming (accessed September 10, 2007).
[76] Maryland Office of the Governor, *Maryland Executive Order 01.01.2007.02*. Available at: http://www.gov.state.md.us/executiveorders/01.01.02.Baystat.pdf (accessed September 10, 2007).
[77] Z.P. Johnston, *A Sea Level Rise Response Strategy for the State of Maryland* (Annapolis, MD: Maryland Department of Natural Resources, 2008).
[78] J. Leach, "Zoning, Subdivision and Site Planning: What Coastal Communities Can Do to Address Sea Level Rise." Presentation at the Virginia Institute of Marine Science Spring 2007 Workshop, *Sea Level Rise & Other Coastal Hazards: the Risk of Coastal Living*. Available at http://ccrm.vims.edu/seminarpresentations/spring_2007/spring_2007_presentations.html (accessed September 10, 2007).
[79] Agriculture and Wildlife Working Group, *Growing Conservation in the Farm Bill* (Washington, DC: Theodore Roosevelt Conservation Partnership, 2007).
[80] Galli, J., *Thermal Impacts Associated With Urbanization and Stormwater Management Best Management Practices* (Washington, D.C.: Metropolitan Washington Council of Governments, 1991).
[81] Properly inflated tires require less energy to get rolling and to maintain speed, are safer, and last longer. Keeping your tires properly inflated can improve fuel economy by as much as 3 percent, reducing emissions of carbon dioxide by an average of 250 lbs per year and cutting fuel costs by as much as 10 cents per gallon. Source: http://www.fueleconomy.gov.

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BBC NEWS

Greenland ice swells ocean rise

By Paul Rincon
BBC News science reporter, St Louis

Greenland's glaciers are sliding towards the sea much faster than previously believed, scientists have told a conference in St Louis, US.

It was thought the entire Greenland ice sheet could melt in about 1,000 years, but the latest evidence suggests that could happen much sooner.

It implies that sea levels will rise a great deal faster as well.

Details of the study, by Nasa and University of Kansas researchers, are also reported in the journal Science.

The comprehensive analysis found that the amount of ice dumped into the Atlantic Ocean has doubled in the last five years.

If the Greenland ice sheet melted completely, it would raise global sea levels by about 7m.

Greenland's contribution to global sea level rise today is two to three times greater than it was in 1996.

Sleeping giant

"We are concerned because we know that sea levels have been able to rise much faster in the past - 10 times faster. This is a big gorilla. If sea level rise is multiplied by 10 or more, I'm not sure we can deal with that," co-author Eric Rignot, from the US space agency's (Nasa) Jet Propulsion Laboratory in California, told the BBC News website.

Previous estimates suggested it would take many hundreds of years for the Greenland ice sheet to melt completely. The new data will cut this timescale, but by how much is uncertain.

> **It takes a long time to build and melt an ice sheet, but glaciers can react quickly to temperature changes**
> Dr Eric Rignot, Nasa

"It depends on how fast the glaciers can go and how sustainable the acceleration can be," said Dr Rignot.

He added: "It takes a long time to build and melt an ice sheet, but glaciers can react quickly to temperature changes."

In 1996, Greenland was losing about 100 cubic km per year in mass from its ice sheet. In 2005, this had increased to about 220 cubic km. By comparison, the city of Los Angeles uses about one cubic km of water per year.

Rising surface air-temperatures seem to be behind the increases in glacier speed in the southern half of Greenland since 1996; but the northward spread of warmer temperatures may be responsible for a rapid increase in glacier speed further north after 2000.

Satellite monitoring

Over the past 20 years, the air temperature in south-east Greenland has risen by 3C.

Warmer temperatures cause more surface melt water to reach the base of the ice sheet where it meets the rock. This is thought to serve as a lubricant, easing the glaciers' march to the sea.

The study's results come from satellites that monitor glacier movement from space.

Rignot and colleague Pannir Kanagaratnam, from the University of Kansas, built up a glacier speed map from the data for 2000 and then used measurements from 1996-2005 to determine how glacier velocity had changed in the last decade.

The researchers plan to continue their monitoring of the Greenland glaciers using satellite data.

The Greenland ice sheet covers 1.7 million sq km and is up to 3km thick.

The scientists described their results at the annual meeting of the American Association for the Advancement of Science.

Story from BBC NEWS:
http://news.bbc.co.uk/go/pr/fr/-/1/hi/sci/tech/4720536.stm

Published: 2006/02/16 18:58:37 GMT

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THE INCREDIBLE ECONOMICS OF GEOENGINEERING

Scott Barrett
Johns Hopkins University School of Advanced International Studies

15 March 2007

Geoengineering—which I shall take to be the deliberate modification of the climate by means other than by changing the atmospheric concentration of greenhouse gases—sounds like an idea conceived in Hollywood.1 To most people, the suggestion seems crazy if not dangerous (Schelling 1996). For better or worse, however, it is a concept that needs to be taken seriously. As I shall explain in this paper, its future application seems more likely than not. This is partly because the incentives for countries to experiment with geoengineering, especially should climate change prove abrupt or catastrophic, are very strong. It is also because the incentives for countries to reduce their emissions are weaker. Geoengineering and mitigation are substitutes.

Indeed, it is mainly because geoengineering and emission reductions are substitutes that the concept lacks "broad support from scientists" (Cicerone 2006: 221).[2] Not all scientists welcomed the recent publication of a paper by Paul Crutzen, a Nobel-prize-winning chemist, on geoengineering.3 To acknowledge the feasibility of controlling the climate deliberately, these scientists fear, undercuts "human resolve to deal with the cause of the original problem, greenhouse gases in the case of climate change" (Cicerone 2006: 224). Crutzen understands this view; he only wrote about the subject reluctantly. He would prefer that emissions of greenhouse gases be cut to an extent that geoeneginering would not be needed. He has only recognized the possible utility of geoengineering now because he despairs about the prospect of emissions being reduced enough, and quickly enough, to avoid dangerous climate change.

---

[*] In my lecture to the British Association for the Advancement of Science, I gave an overview of my new book on global public goods (Barrett 2007), of which the topic of this paper is but one example. I have used the opportunity of this special issue to expand upon and recast my brief discussion of this topic as presented in my lecture and in the first chapter of this book.

[1] Geoengineering is defined in various ways in the literature. To some, it includes planting trees to absorb CO2. To others, it may involve carbon capture and storage, or enhanced take up of CO2 by the oceans. For a comprehensive treatment, see Keith (2000). Here I focus deliberately on an option that differs fundamentally from "carbon management."

[2] Economists have been perhaps a little more willing to discuss the concept; several distinguished economists, for example, participated in the Panel on Policy Implications of Greenhouse Warming (1992). Most economic analyses of climate change, however, have ignored geoengineering. I did not refer to it in my earlier book (Barrett 2005). It is not mentioned in *The Stern Review* (Stern 2007).

[3] In the same issue of *Climatic Change*, Ralph Cicerone, the president of the National Academy of Sciences, wrote, "I am aware that various individuals opposed the publication of Crutzen's paper, even after peer review and revisions, for various and sincere reasons that are not wholly scientific" (Cicerone 2006: 221).

The suggestion here is that it would be better if countries could commit themselves not to resort to geoengineering. That way, the world would have no alternative but to reduce emissions.

There are, however, serious incentive problems associated with reducing emissions—problems that explain why so little has been done thus far, even with geoengineering being little discussed as a possible fallback. Indeed, even if emissions were reduced sharply and soon, we may prefer to keep the geoengineering option open because of the residual risk of abrupt climate change.

Moreover, it may be impossible for countries to keep a commitment to abstain from experimenting with geoengineering. The incentives for countries to reduce emissions on a substantial scale are too weak, and the incentives for them to develop geoenegineering are too strong, for commitment to be a realistic prospect. Indeed, these two incentives combined are so powerful that many countries may be prepared to develop and deploy geoengineering unilaterally. That, I believe, is the greater danger.

Finally, and following on these two observations, a new governance arrangement is needed that places climate change policy in a broader context, recognizing that the objective should be to reduce climate change risk and that this requires a combination of efforts—on reducing emissions, certainly; but also on R&D into new energy technologies, on adaptation assistance to the poorest countries, and, yes, on geoengineering. This new framework should determine the circumstances under which geoengineering is to be permitted and proscribed.

A brief overview of geoengineering

Two fundamental forces determine the Earth's climate: the amount of solar radiation that strikes the Earth and the amount of this radiation trapped by the atmosphere. The latter effect is determined by the concentration of greenhouse gases. The former depends on the solar cycle and the Milankovitch cycles that determine, over very long periods of time, how solar radiation is distributed.

Policy can shape these two forces by means of greenhouse gas and solar radiation management.4 There does not exist a widely accepted definition of geoengineering, but as noted in the introduction I shall take it to mean deliberate climate modification by solar radiation management. This essentially means deflecting sunlight.

This already happens naturally. The eruption of Mount Pinatubo in the Philippines in 1991 injected huge quantities of sulfur dioxide into the stratosphere, lowering the Earth's surface temperature by about 0.5°C the year following the eruption (Crutzen 2006). Human activities are also causing backscattering now—unwittingly. When coal is burned, sulfate particles are thrown

[4] Climate change is also determined by land surface properties, and policy could seek to change the Earth's surface albedo. However, this approach is also problematic and less efficient than atmospheric scattering; see MacCracken (2006).

into the troposphere, increasing albedo.[5] These particles, however, are harmful to human health and ecosystems; they should be, and increasingly are being, reduced. Indeed, it is partly for this reason that solar radiation has increased. Reducing concentrations of sulfate particles exacerbates "global warming."

The sulfate particles we put into the atmosphere are inefficient deflectors. Particles injected higher up into the stratosphere linger for longer—years rather than weeks. Engineered particles are expected to perform better still, reducing the total mass of material that would have to be injected to achieve a given cooling effect.

Geoengineering is a stopgap measure, a "quick fix," a "Band-Aid." It is akin to adding ground limestone to Sweden's pH-sensitive lakes and soils. Though only reductions in acidic emissions can prevent acid rain, liming preserves pH balance; it prevents acid rain damage. Geoengineering would have a similar effect. It would not address the underlying cause of climate change, but if it worked as intended it would prevent temperatures from rising against a background of elevated atmospheric concentrations of greenhouse gases.[6]

Its main advantage might be in stemming abrupt and catastrophic climate change. Abrupt climate change would take place over a period of perhaps a decade or two—too short a period for emission reductions to be able to stop it. By contrast, the climate response of albedo enhancement would take hold in a matter of months (Crutzen 2006). Catastrophic climate change would likely unfold over a number of centuries, but avoiding it will require a technological revolution, and geoengineering might help to "buy time" to develop and diffuse these new technologies (Wigley 2006).

Here is another way to look at this: It has been widely suggested that global mean temperature should not be allowed to increase by more than 2° C. At a concentration level of 550 parts per million CO2, mean global temperature is likely to rise 1.5° to 4.5° C.[7] Put differently, to be confident (but not certain) of limiting temperature change to 2° C, concentrations would have to be capped at a level far below 550 ppm—to a level more like 380 ppm (Caldiera, Jain, and Hoffert 2003: 2052). That would mean capping concentrations at the current level, and without a mass adoption of "air capture," this goal is essentially unattainable. Geoengineering might therefore be an indispensable ingredient of a policy aiming to ensure that mean global temperature rises by no more than 2° C.

Would geoengineering work? As mentioned previously, the effect of volcanoes and sulfate pollution has been measured; we know that these natural and inadvertent interventions work. So far, the efficacy of deliberate climate engineering has been demonstrated only in computer models. Wigley (2006: 452) reasons that, since the Mount Pinatubo eruption did not "seriously disrupt the climate system," deliberately adding the same loading should "present minimal climate risks." Simulating the effects of adding a Mount Pinatubo eruption every year, every two

[5] The condensation trails left by jet aircraft may have a similar effect; see Travis et al. (2002).
[6] For a more general discussion of quick fixes, see Sterner et al. (2006).
[7] According to the latest IPCC assessment (IPCC 2007: 9), climate sensitivity is "*likely* to be in the range of 2 to 4.5° C with a best estimate of about 3° C, and is *very unlikely* to be less than 1.5° C."

years, and every four years, he finds that the biennial eruption "would be sufficient to offset much of the anthropogenic warming expected over the next century."

Though global mean temperature can be controlled by changing solar reflectivity as well as by limiting greenhouse gas concentrations, the physics of these approaches differ. They may have different effects on the geographic distribution of temperatures. Computer simulations by Govindasamy and Caldeira (2000) and Govindasamy, Caldeira, and Duffy (2003), however, have shown that geoengineering would likely have little effect on the spatial pattern of surface temperatures. The distribution of temperature seems to be determined by more fundamental forces.

Geoengineering would affect more than the climate; it would have other environmental effects. Stratospheric aerosols could destroy ozone, as did the aerosols released by Mount Pinatubo. However, this damage is expected to be modest (Robock 2002). According to Paul Crutzen (2006: 215), a co-recipient of the 1995 Nobel Prize in chemistry for research on the ozone layer, the geoengineering needed to compensate for a doubling in carbon dioxide concentrations "would lead to larger ozone loss but not as large as after Mount Pinatubo"—and this against a background of expected rising ozone levels overall because of the success of the Montreal Protocol. As well, the risks from geoengineering would be bounded; aerosols pumped into the stratosphere would survive only a few years, much less than greenhouse gases (some of which can persist for more than a millennium). Geoengineering may even offer environmental benefits, the main one being the blocking of harmful UV radiation by engineered particles (Teller et al. 2003). Here again, however, there would be a trade off, as it is likely that such particles would also extend the atmospheric life of other greenhouse gases, reducing the overall cooling effect.

Particles thrown into the stratosphere would be transported towards the poles (their residency would thus be maximized if released over the equator) where they would "rain out." The effects may not be significant, however, since the amounts that would be added are a small fraction of the current input by pollution and volcanic eruptions (Crutzen 2006: 213).

Like volcanic eruptions, geoengineering would change the color of the sky. Volcanic particles whiten the sky by day (an environmental loss, presumably, though one that is already being caused by atmospheric pollution), but make sunsets and sunrises more vibrant (Crutzen 2006).

Some of the consequences of geoengineering may surprise us. Geoengineering would constitute a large-scale experiment (though that is also true of the experiment geoengineering is meant to correct, that of rising concentrations of greenhouse gases). Computer simulations offer a hint as to the likely consequences, but they can provide no more than this. The geoengineering experiment could be undertaken on a limited scale—a small volume of aerosols might be added initially, and released over the higher latitudes. Very importantly, the experiment could be halted, should adverse effects appear. Barring irreversibilities, the effects of geoengineering—positive and negative—would only be transitory.

Still, geoengineering amounts to putting something into the environment that wasn't previously there; reducing emissions, by contrast, amounts to not adding something that wasn't there. Of the two approaches, mitigation is the more conservative option—the reason it is preferred by scientists. However, the risks are not so one-sided. Mitigation cannot be relied upon to be benign. To reduce emissions substantially and in the near term will require an expansion in nuclear power, creating problems for safety, waste storage, and proliferation (Ansolabehere et al. 2003). Carbon capture and storage holds the promise of allowing countries to burn coal without releasing greenhouse gases into the atmosphere, but sinking carbon into the oceans would also amount to adding something to the environment that wasn't previously there; it would therefore also entail environmental risk (Anderson and Newell 2004).

One effect of geoengineering is unambiguous: it would do nothing to address the related problem of ocean acidification. The oceans absorb a portion of the carbon dioxide pumped into the atmosphere. This decreases the pH level of the oceans and is likely to change the process of calcification, endangering animals such as corals (which may, however, be bleached by rising ocean temperatures long before geoengineering is ever tried) and clams. Limestone could be added to the oceans, just as we have added limestone to acid-sensitive lakes, but liming is likely to be feasible only for certain sensitive areas (Royal Society 2005). It is not a comprehensive answer to the problem.

Geoengineering economics

The economics of geoengineering are—there is no better word for it—incredible. Upon reviewing the options in depth, the Panel on Policy Implications of Greenhouse Warming (1992: 460) concluded by saying that, "one of the surprises of this analysis is the relatively low costs at which some of the geoengineering options might be implemented." The Panel (1992: 452, 454) calculated that adding stratospheric aerosol dust to the stratosphere would cost just pennies per ton of CO2 mitigated. Drawing on this study, Nordhaus (1994: 81) concluded that offsetting all greenhouse gas emissions today would cost about $8 billion per year—an amount so low that he treats the geoengineering option as being costless. According to Teller *et al.* (2003: 5), engineered particles would be even cheaper (mainly because of the reduced volume of material that would need to be put into the stratosphere); they estimate that the sunlight scattering needed to offset the warming effect of rising greenhouse gas concentrations by the year 2100 would cost just $1 billion per year. Keith (2000: 263) thinks this is an optimistic estimate, but says that, "it is unlikely that cost would play any significant role in a decision to deploy stratospheric scatterers because the cost of any such system is trivial compared to the cost of other mitigation options."

Taking into account the effect of engineered particles on scattering harmful UV radiation, Teller and his colleagues calculate that this health-related benefit for the U.S. alone would exceed the total cost of geoengineering by more than an order of magnitude (Teller et al. 2003: 5-6). If correct, the economics are even more favorable than suggested above.

Deliberate climate modification would also allow carbon dioxide concentrations to remain elevated—an aid to agriculture.[8]

Just as important as the cost of geoengineering relative to emission reductions is the nature of these two options. Geoengineering constitutes a large project (Schelling 1996). By means of this technology, a single country, acting alone, can offset its own emissions—and those of every other country. By contrast, mitigating climate change by reducing emissions requires unprecedented international cooperation and very substantial costs. Stabilizing atmospheric concentrations requires a 60 to 80 percent cut in CO2 emissions worldwide. In the years since the Framework Convention on Climate Change was adopted, global emissions have risen about 20 percent. Even if the Kyoto Protocol is implemented to the letter, global emissions will keep on rising. So will concentrations. Theory points to the difficulty in achieving substantial and wide scale cooperation for this problem, and the record to date sadly supports this prediction.[9]

A quick calculation hints at the temptation presented by geoengineering. According to Nordhaus and Boyer (2000: 131), climate change might cost the United States alone about $82 billion in present value terms. Using a three percent rate of discount, this is equivalent to an annual loss of about $2.5 billion. If the United States cut its emissions, it could reduce this damage somewhat. If it turned to geoengineering, it could eliminate this damage. If geoengineering is as cheap and effective as is claimed, the U.S. might prefer the geoengineering option. So, of course, might other countries.

Denote the benefits to Country i by Bi and assign numerical labels to countries that reflect their relative benefits, such that $B1 > B2 > \ldots > BN$. Finally, let the cost of geoengineering be denoted C. Then, so long as $B1 > C$, we can be pretty sure that geoengineering will be tried (using it would be the Nash equilibrium). It may not be tried by Country 1. Any country j for which $Bj > C$ would be willing to try it, should all others not try it. Countries might even agree to pool their resources, to share the costs. We cannot predict which country or group of countries will bear the cost, but it is clear that the incentive for geoengineering to be tried is very strong so long as the costs are low. Even if the costs turn out to be much higher (such that $C > B1$), and no country has an incentive to try geoengineering unilaterally, a coalition of k countries would have an incentive to do so collectively so long as $B1 \ldots Bk > C$. (In this case, using geoengineering would be a Nash equilibrium but so would not using geoengineering).

Climatologist Michael MacCracken (2006: 238) argues that, "Although it might be conceivable for one nation to actually commit to such a program, it seems rather unlikely that a global coalition of nations could be kept together to sustain such a diversion of

[8] Govindasamy et al. (2002) estimate that the global dimming needed to offset a doubling in CO2 concentrations (a 1.8 percent reduction in solar flux) would reduce net primary productivity by about 3 percent, whereas the higher CO2 would increase net primary productivity about 76 percent. Though beneficial for agriculture overall, these changes would also affect the balance of sensitive ecosystems.

[9] On the theory of cooperation in this area, see Barrett (2005). In Barrett (2006a) I consider what I believe to be a particularly promising approach. However, even here the prognosis is discouraging. It was only after writing this paper that I began to consider seriously the possibility of geoengineering.

resources for a task that would seem, to the typical citizen, to generate no immediate or direct benefits." I disagree. There is no need for countries to commit to sustaining a geoengineering intervention. It is true that there are a huge number of Nash equilibria to the cost-sharing game. But were a geoenegineering effort to be shut off, the climate would respond very rapidly (Wigley 2006). Any country that had an incentive to join a coalition of countries in financing a geoengineering project initially would have at least as strong an incentive to continue with it later—unless, of course, in the meantime, previous efforts at reducing emissions succeeded in lowering atmospheric concentrations.

This last possibility is the scenario examined by Wigley (2006). He considers the role that geoengineering might play in "buying time" for a policy needed to stabilize concentrations. To be more specific, he shows how geoengineering could be used to smooth the hump caused by overshooting a concentrations target. This may be an attractive use of geoengineering, but in this case there is a commitment problem. If geoengineering should prove benign, the incentive to reduce atmospheric concentrations would be muted. A promise to use geoengineering only temporarily may thus lack credibility.

Geoengineering governance

Ironically, the attributes that make geoengineering attractive also make it worrying. Because it consists of a single project, it can be undertaken unilaterally or minilaterally. Because of its low cost, the incentives for it to be tried are very strong. The consequences of one country or a small number of countries using it, however, would be global; and they might not all be welcome (Schneider 2001).

So, who is to decide whether geoengineering should be deployed? Should a country be allowed to do so unilaterally? Could it be prevented from doing so? Some countries are expected to benefit from climate change, at least gradual climate change through this century. According to Nordhaus and Boyer (2000: 131), for example, Russia, China, and Canada would all gain. Would these countries need to be compensated for damages resulting from a geoengineering intervention to limit climate change? If the losers from climate change use geoengineering to cool temperatures, might the winners use geoengineering to *absorb*, rather than to scatter, radiation? (Might there be geoengineering wars?) Could *they* be prevented from doing so? Would countries be allowed to engineer any temperature, or would they only be permitted to limit change from the recent historical average? The world's poorest countries are especially vulnerable to climate change, and yet they are likely to be the least able to develop and deploy a geoengineering effort. Should the more capable states be required to do so for them?10 Should they be made to pay compensation if they do not? Suppose geoengineering affected the spatial distribution of climate, even if it succeeded in preventing the global (average) climate from changing. Should the countries adversely affected be compensated? How would damages be

10 There is a similarity here with the new norm of "the responsibility to protect," which requires that the major powers intervene to stop genocide. As the current situation in Darfur shows, the problem here is that the major powers are declining to act; they are declining to fulfill their responsibility. See the concluding chapter of Barrett (2007).

determined? Which countries would be expected to pay compensation? How could the obligation to pay be enforced? What about countries that have different attitudes towards risk, or that object to the idea of deliberately altering the climate whatever the benefits may be? Should their views be heeded?

Two precedents offer a glimpse into how these concerns might be addressed. The first concerns experiments with a different kind of particle. The Large Hadron Collider being built in Europe is intended to test the Standard Model of particle physics. The knowledge gained from this project will be a global public good, but there is a small chance that the experiment could create something called a strangelet—an object that, by a process of contagion, might possibly "transform the entire planet Earth into an inert hyperdense sphere about one hundred metres across" (Rees 2003: 121). It is even conceivable that the particle smashes might create a growing black hole—a phenomenon that might destroy not just the Earth but the entire universe. A report written for the backers of the Large Hadron Collider concludes that there is "no basis for any conceivable threat" (Blaizot et al. 2003: iii). But the likelihood of a strangelet being created is impossible to calculate with certainty, since the experiment has never taken place before. Existing theories are reassuring, but they have not been tested. And do we really want to test them? Are we sure that the global public good of new knowledge outweighs the global public bad of the risk of annihilation?

More importantly, who should decide whether the experiments should go ahead? So far, the decision has been left to the parties who are financing the project—the 20 European members states of CERN (officially, the European Organization for Nuclear Research), the organization that is building and that will run the Large Hadron Collider, and its partners on this project—India, Japan, Russia, and the United States.[11] But should other countries have been consulted? Should other countries have a veto?

The second precedent concerns the remaining stocks of smallpox virus. Smallpox was eradicated in 1977, yielding every country a huge dividend (Barrett 2006b). Provision of this global public good meant that people no longer needed to die of this disease. It meant also that there was no longer a need for people to be vaccinated. Unfortunately, reaping this dividend has exposed countries to a new risk. If smallpox were somehow reintroduced today, the world would be more vulnerable than ever to an epidemic. So long as smallpox exists, this risk remains. Concern about a possible accidental release caused laboratories around the world to destroy or transfer their stocks; by 1983, known stockpiles of smallpox virus were held by just two World Health Organization (WHO) "collaborating centers," one in Atlanta and the other in Moscow. But were these the *only* remaining stocks left? Unfortunately, no one could be sure. Some people suspected that covert stocks might have been retained by other states. That concern persists today.

[11] The members of CERN include Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Norway, the Netherlands, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, and the United Kingdom.

What to do with the last two known stockpiles? In 1986 and again in 1990, the WHO's Committee on Orthopoxvirus Infections recommended that the stocks held in Atlanta and Moscow should be destroyed. But while destruction would eliminate the risk of an accidental release, it would also foreclose the option of using the remaining stocks to develop improved diagnostic tools, antiviral drugs, and a novel vaccine—innovations that would benefit the whole world should covert stocks exist and should smallpox virus be released deliberately some day. As with geoengineering, the decision to destroy the remaining stores of smallpox entails a risk-risk tradeoff. It also has implications for every country.

Again the question: Who should decide? The two states that possess the virus obviously have the upper hand (just as the major powers would have the upper hand in developing a geoengineering project), but being WHO collaborating centers, the labs in Atlanta and Moscow are obligated to serve the global interest.

In 1998, the WHO polled its 190 members. Did they want the last known stocks to be retained or destroyed? The survey revealed a split. Russia wanted to hold onto its samples; Britain, France, Italy, and the United States were undecided; every other country (74 other countries responded) favored destruction. Concerned about the risk of a bioterrorist attack, the United States changed its position in 1999, asserting a need to keep its stockpile. When the World Health Assembly met shortly after this, a compromise was worked out. A resolution was proposed that reaffirmed the goal of *eventual* destruction but permitted Russia and the U.S. to retain their stocks for research purposes for a period of three years. The resolution passed by acclamation. Later the reprieve was extended; and, today, smallpox virus is still kept at the two WHO centers. Inspectors have satisfied the WHO's Advisory Committee on Variola Virus Research that the stocks are secure, and the Committee has verified that the research undertaken at both labs has progressed. They have also confirmed, however, that the job is not yet finished. Their judgment is that there is still reason to retain smallpox for research purposes.

The arrangements surrounding the decision to retain the smallpox stocks are very different from those connected with the conduct of possibly dangerous experiments. The latter are being undertaken by a relatively small number of countries, without wider consultation let alone approval. The smallpox decision, by contrast, has been undertaken in a setting in which all the world's countries were invited to take part. To be sure, in this case the power relations among countries are vastly unequal. But the process that emerged favored consensus—an especially fortunate outcome. Since every country will be affected by whatever is decided, it is as well that each should agree with the decision. As matters now stand, the situation with geoengineering is more akin to the regime for carrying out particle collider experiments than to the smallpox decision. Currently, there is no institutional arrangement that says what countries are allowed to do or not to do as regards geoengineering. By default, therefore, countries are pretty much free to explore geoengineering options or not as they please. It may be unlikely that countries would seek to act unilaterally (Bodansky 1996), or as part of a "coalition of the willing," but that possibility will remain unless and until climate engineering is brought into an institutional framework of some kind.

How to proceed? Three steps are needed. First, the possibility of geoengineering should be examined in detail by the Intergovernmental Panel on Climate Change, in a special report. Its pros and cons need to be evaluated, and all countries need to be made aware of them. Second, and drawing on this technical work, the Framework Convention on Climate Change should be revised. This agreement has the great advantage of having nearly universal participation (the only non-parties are Andorra, Brunei, the Holy See, Iraq, and Somalia, and these states are free to join when their circumstances permit). Currently, however, the Framework Convention embraces the objective of stabilizing atmospheric concentrations of greenhouse gases; it does not mention geoengineering. A revised convention should emphasize the need to reduce climate change risk—a broader objective that would encompass not only efforts to reduce atmospheric concentrations but also adaptation (which is mentioned in the Convention), R&D into new energy technologies, and geoengineering. Finally, and building upon the first two steps, a new protocol should be added that specifies whether and under what conditions geoengineering should be allowed (even if only for research purposes), or possibly even required, and how the costs of any efforts should be shared.[12]

Conclusion

Mitigating, forestalling, or averting global climate change is a global public good. Supplying it by means of reducing emissions is vulnerable to free riding. Too few countries are likely to participate in such an effort, those that do participate are likely to reduce their emissions by too little, and even their efforts may be overwhelmed by trade leakage (Barrett 2005). Geoengineering presents a very different set of incentives. A single country can deploy a geoengineering project on its own—and the economics of geoengineering are so attractive that it seems likely that a country, or perhaps a small group of countries, may want to try to do so at some point in the future, especially should the worst fears about climate change ever unfold.

The challenge posed by geoengineering is not how to get countries to do it. It is to address the fundamental question of who should decide whether and how geoengineering should be attempted—a problem of governance (Barrett 2007). Failure to acknowledge the possibility of geoengineering may or may not spur countries to reduce their emissions, but it will mean that countries will be unrestrained should the day come when they would want to experiment with this technology.13 This, to my mind, is the greater danger.

[12] Cost sharing has the advantage of widening decision making to include a greater number of countries; see Barrett (2007), Chapter 4. The conditions noted here could include a moratorium, as suggested by Cicerone (2006).

[13] A secondary problem is that the countries capable of using geoengineering may not use it to help countries in need but lacking such a capability. This is allied to the problem of the rich countries providing adaptation assistance to the poor, and another reason why all the policy dimensions of climate change need to be evaluated jointly.

References

Anderson, S. and R. Newell (2004). "Prospects for Carbon Capture and Storage Technologies." *Annual Review of Environment and Resources*, 29: 109-142.

Ansolabehere, S., J. Deutch, M. Driscoll, P.E. Gray, J..P. Holdren, P.L. Joskow, R.K. Lester, E.J. Moniz, and N.E. Dodreas (2003). *The Future of Nuclear Power: An Interdisciplinary MIT Study*, Cambridge, MA: Massachusetts Institute of Technology.

Barrett, S. (2007), *Why Cooperate? The Incentive to Supply Global Public Goods*, Oxford: Oxford University Press.

Barrett, S. (2006a) "Climate Treaties and 'Breakthrough' Technologies." *American Economic Review, Papers and Proceedings* 96(2): 22-25.

Barrett, S. (2006b) "The Smallpox Eradication Game." *Public Choice* 130: 179-207.

Barrett, S. (2005), *Environment and Statecraft: The Strategy of Environmental Treaty-Making* (paperback edition). Oxford: Oxford University Press.

Blaizot, J.-P., J. Iliopoulos, J. Madsen, G.G. Ross, P. Sonderegger, and H.-J. Specht (2003). *Study of Potentially Dangerous Events During Heavy-Ion Collisions at the LHC: Report of the LHC Safety Study Group*. Geneva: CERN 2003-001.

Bodansky, D. (1996). "May We Engineer the Climate?" *Climatic Change* 33: 309-321.

Caldeira, K., Jain, A. K., and Hoffert, M. I. (2003) "Climate sensitivity uncertainty and the need for energy without CO2 emission," *Science* 299: 2052-2054.

Cicerone, R.J. (2006). "Geoengineering: Encouraging Research and Overseeing Implementation." *Climatic Change* 77: 221-226.

Crutzen, P.J. (2006). "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?" *Climatic Change* 77: 211-219.

Govindasamy, B. and Caldeira, K. (2000) "Geoengineering Earth's Radiation Balance to Mitigate CO2-induced Climate Change," *Geophysical Research Letters* 27(14): 2141- 2144.

Govindasamy, B., Caldeira, K., and Duffy, P. B. (2003) "Geoengineering Earth's Radiation Balance to Mitigate Climate Change from a Quadrupling of CO2," *Global and Planetary Change*, 37: 157-168.

Govindasamy, B., S. Thompson, P.B. Duffy, K. Caldeira, and C. Delire (2002). "Impact of Geoengineering Schemes on the Terrestrial Biosphere." *Geophysical Research Letters* 29(22), 2061, doi.1029/2002GL015911, 2002.

Intergovernmental Panel on Climate Change (2007), *Climate Change 2007: The Physical Science Basis, Summary for Policymakers*; available at http://www.ipcc.ch/SPM2feb07.pdf.

Keith, D.W. (2000). "Geoengineering the Climate: History and Prospect," *Annual Review of Energy and Environment*, 25: 245-284.

MacCracken, M.C. (2006). "Geoengineering: Worthy of Cautious Evaluation?" *Climatic Change* 77: 235-243.

Nordhaus, W.D. (1994). *Managing the Global Commons: The Economics of Climate Change*. Cambridge, MA: MIT Press.

Nordhaus, W. D. and Boyer, J. (2000) *Warming the World: Economic Models of Global Warming*, Cambridge, MA: MIT Press.

Panel on Policy Implications of Greenhouse Warming (1992), *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base*. Washington, DC: National Academy Press.

Rees, M. (2003). *Our Final Hour*, New York: Basic Books.

Robock, A. (2002) "The Climatic Aftermath," *Science* 295: 1242-1243. Royal Society (2005) Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide, London: The Royal Society.

Schelling, T.C. (1996). "The Economic Diplomacy of Geoengineering." *Climatic Change* 33: 303-307.

Schneider, S.H. (2001). "Earth Systems Engineering and Management." *Nature* 409: 417-421.

Stern, Nicholas (2007), Cambridge: Cambridge University Press. *The Economics of Climate Change: The Stern Review*

Sterner, T., M. Troell, S. Aniyar, S. Barrett, W. Brock, S. Carpenter, K. Chopra, P. Ehrlich, M. Hoel, S. Levin, K-.G. Mäler, J. Norberg, L. Pihl, T. Söderqvist, J. Wilen, J. Vincent, and A. Xepapadeas (2006). "Natural Disasters and Disastrous Policies," *Environment* 48(10): 20-27.

Teller, E., Hyde, R., Ishikawa, M., Nuckolls, J., and Wood, L. (2003) "Active stabilization of climate: inexpensive, low risk, near-term options for preventing global warming and ice ages via technologically varied solar radiative forcing," Lawrence Livermore National Library, 30 November.

Travis, D.J., A.M. Carleton, and R.G. Lauritsen (2002). "Contrails Reduce Daily Temperature Range." *Nature* 418: 601.

Wigley, T.M.L. (2006). "A Combined Mitigation/Geoengineering Approach to Climate Stabilization." *Science* 314: 452-454.

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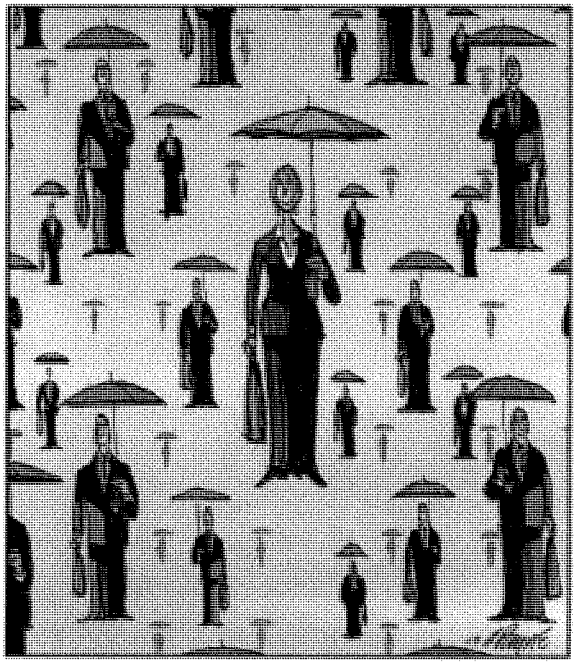

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Risky Gamble

Reducing emissions of greenhouse gases may be well intentioned and even helpful. But as the sole strategy for climate change control it is nevertheless inflexible, expensive, risky, and politically unrealistic, according to this government economist. Such a strategy could even make matters worse. Fortunately, there is a better solution

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The environmental community has done a great planetary service by highlighting the need for worldwide climate change control. There has been remarkably little analysis of the specific problems posed by global warming, however, and of the best ways to respond to them. Instead, most advocates have endorsed a panacea that I will characterize as exclusive regulatory de-carbonization, or ERD. They argue that since greenhouse gases are the cause, the solution must be mandated cuts in emissions or possibly removal of gases already in the atmosphere. This is a well-meaning conclusion consistent with previous pollution control efforts. But while ERD can help, recent research shows that it would not be enough to solve the most serious problems posed by a rapidly warming world. Fortunately, there is an option that would solve most of these problems, more quickly, effectively, and efficiently, and without the need for alterations in lifestyle: solar radiation management, or SRM. The one problem that cannot be resolved through such an approach (detailed below) may well be beyond the capability of regulatory de-carbonization as well, so SRM may be our best hope of coping with a changing world.

By now it is well known that efforts to reduce emissions of GHGs in only a few countries — whether under the Kyoto Protocol, regional agreements, or national programs — cannot achieve the temperature limits the European Union believes are necessary to avoid dangerous changes to the environment. What is less well known is that these measures would be unlikely to do so even with the full cooperation of every person and every nation on the Earth. Considering the high levels of atmospheric GHGs and the as-yet unrealized warming from climate system lag, this disturbing conclusion is hard to escape. It is made worse by factoring in the drastic, immediate cuts that would be required; the unwillingness of people, and therefore politicians, to pay the costs and endure the requisite reductions in energy services; the strong economic incentives to continue increasing energy services; and the extreme difficulty of achieving and maintaining a precise heat balance for the Earth through what would amount to centralized world energy planning.

Even worse, pursuing regulatory de-carbonization as the only control strategy — whether through cap-and-trade, carbon taxes, efficiency standards, bio-fuel subsidies, or plain-old facility emissions limits — is likely to bring about the very effects that the environmental community has worked so hard to publicize, by diverting the world's attention and resources from

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more effective solutions. Both in financial terms and in lost opportunities, the cost of this single-minded approach is likely to be huge.

Our myopia in the global warming area is caused in part by a confusion of goals. Too often the end result of climate change control is expressed as reducing GHG emissions, even though this is merely a means. Thus the first task is to identify what the risks are and establish performance measures to evaluate proposed solutions. There appear to be three major problems to be solved:

Problem 1. Gradually increasing world temperatures and the immediate effects on humans and ecosystems is the most well known risk. Some people (those living in colder climes) *may* welcome this. Others (those living in coastal areas) will probably be flooded out. Almost everyone will face adaptation costs.

Problem 2. Dangerous, self-reinforcing climate change. This appears to be the most critical risk. The concerns most often mentioned are release of large quantities of methane (a potent GHG) from thawing permafrost or from under the ocean floor, melting of the Greenland and West Antarctic ice sheets, and a breakdown of the ocean currents that warm Western Europe. Any of these could cause a regional or global disaster.

Solar radiation management could be a far more effective and economical climate policy

Problem 3. Non-temperature effects of increasing GHGs, particularly the effects of increasing carbon dioxide levels on the oceans. The resulting acidification is believed to be already affecting shellfish and coral reefs. This risk is the most difficult to solve.

Although most public discussion has addressed the first risk, the technical discussion has rightly centered on the second as the basis for setting de-carbonization goals, since the feared environmental changes could well be catastrophic and possibly irreversible. To this end, the EU has adopted a target of restricting global warming to less than a 2° Celsius (3.6° Fahrenheit) increase from pre-industrial levels to prevent "dangerous . . . interference with the climate system." This goal has also been implicitly adopted by many environmentalists and climatologists and the British, German, and Swedish governments.

Recent modeling work, however, suggests that the proposed implementation of this goal by all four of these jurisdictions would actually result in a near certainty of more than a 2°C increase if applied worldwide. Research published this year by James Hansen, head of NASA's Goddard Institute for Space Studies, and others supports the view that even smaller increases may be dangerous. Worse, a 2007 study by Nathan Rive of the Center for International Climate and Environmental Research in Oslo can be used to show that Hansen's prediction of a 15-foot rise in sea level by 2100 because of disintegrating ice sheets cannot be avoided by achievable emissions reductions. This would mean that without mega-engineering projects to protect them, London, Miami, Mumbai, New York, Tokyo, Shanghai, and much of the Netherlands and Bangladesh, among other regions, would be under water by the end of this century, unless some other approach is used to control global temperatures. Al Gore has envisioned a 20-foot sea level rise and like Hansen advocates the use of ERD.

Even if Hansen's predictions should be wrong, the Rive study also shows that the world would need to reduce GHG emissions by 80 percent to obtain a mere 50 percent chance of preventing a 2°C increase. The marginal cost of abatement would be $3,500 per ton of carbon in this scenario, assuming average projections and early action. This is 10 or more times higher than most previous estimates. Naturally, most people would not want just a 50 percent chance of avoiding the risks posed by Problem 2. Given current GHG concentrations, however, a more acceptable 75 percent chance of avoiding such risks is probably unachievable. A 10-year delay would make even a 50 percent chance unachievable.

Another way of looking at this problem is the reduction in energy use needed to achieve even this modest risk reduction. Even when future economic growth is left out of the calculation, global energy

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efficiency per person would have to be increased by roughly 87 percent or human services provided by energy use reduced by 87 percent per person, or some combination of the two. (The reductions required to meet Hansen's concerns would be even larger, if they were achievable.) Energy efficiency can be increased, but only slowly and at considerable cost. It appears unlikely that all the reductions that would be needed could be implemented rapidly enough to meet the 2°C target using only energy efficiency measures, particularly inexpensive ones.

Alternatively, energy services could be cut, either voluntarily or by government mandate. This won't be easy. Stephen Pacala and Robert Socolow of Princeton's Carbon Mitigation Initiative propose to reduce per capita average vehicle-miles traveled from 10,000 annually to 5,000 through better urban design, mass transit, and telecommuting. But to entice drivers out of their vehicles for half their trips would require monumental social investments and individual subsidies; the more likely prospect is coercion. The even more drastic proposal for individual emission rationing reported to be under consideration in Great Britain is a logical extension of the ERD approach, but it is difficult to see how it would attract much support. While increased energy efficiency may eventually contribute significantly, the deep, almost immediate cuts in energy services required to stay below 2°C is politically unrealistic.

Too often the end result of climate change control is expressed as reducing GHGs, even though this is only a means

Avoiding Problem 2 is thus either impossible or very risky through ERD. The limited experience to date is that those jurisdictions with some of the most active programs (such as California and Britain) have been roughly holding their own in recent years. Given economic and population growth, this may be the most that can be achieved by regulatory de-carbonization through energy efficiency and reduced energy services. Even if more can be achieved in particular countries, it would not approach the 80 percent needed on a worldwide basis. Except under special circumstances, such as the collapse of Eastern European industry after 1989, most countries have experienced a gradual increase in emissions, and some are growing rapidly. Most countries have also been unwilling or unable to participate in emission cuts. More than governmental cooperation would be needed, but the idea that all the people of the world would cooperate to make something effective happen is unlikely.

ERD probably won't solve Problem 3, ocean acidification, either. Though it has received scant attention, the projected change in pH of the world's oceans may be the most constraining in terms of the degree of control required. One prominent scientist working in the field, Ken Caldeira of the Carnegie Institution of Washington's Department of Global Ecology, has stated that human-caused carbon dioxide emissions need to be reduced by 98 percent in order to save the world's coral reefs. The 80 percent global reductions believed necessary to have a 50 percent probability of meeting the 2°C target are already practically infeasible; a 98 percent cut would require that human-caused emissions return almost to pre-industrial levels.

A Notable Lack of Candor

Perhaps the most unfortunate aspect of the disjunct between the necessary and the possible is that many of the technical experts advocating ERD have not been forthright about explaining the needed sacrifices or the small chance of success to the public. A worrisome scenario is that politicians who impose significant reductions would be voted out of office and less stringent measures enacted to take their place.

A central problem with ERD is the fact that most of the world would have to drastically reduce GHG emissions if the 2°C temperature goal is to be met, not just a few countries. Reductions by only the major developed countries may decrease the growth in emissions but cannot meet this goal. So far the less developed world has shown little willingness to impose reductions, and is not likely to do so until their citizens demand it. That would require the same sort of concerted public information effort that has occurred in the United States, Europe, and Japan. The major existing measure to coordinate international reductions, the Kyoto Protocol, suffers from this problem and is furthermore unenforceable. It is unlikely to achieve even its modest goals. ERD supporters respond that if only the United States were to enact drastic reductions, the rest of the world would come along. Although there might be advantages in the United States' showing leadership, if the intent is to influence the behavior of the rest of the world, we would have more leverage before we enact stringent reductions because we could still bargain. Enacting them first would also put the United States at a competitive disadvantage in the likely event that not everyone enacts equivalent cuts.

In sufficiently wealthy countries where the change in energy costs may have a smaller impact on the public, it may be possible for politicians to persuade their constituents to accept some measures involving increased energy efficiency if they do not impose too large a burden or result in the loss of too many jobs, but in less developed countries, where prices of com-

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mon forms of energy are often subsidized due to strong popular demand, even increases in prices due to using more energy efficient devices could easily prove politically unpalatable.

Proponents of GHG control argue that the cost would be just a few percent of GDP and that future growth will be many times the costs involved. Even if these broad generalizations were correct, those who will have to pay these costs, particularly if it is not a very broad cross-section of the population, will object strongly. They will see it as a tax rather than an investment in the future.

There are strong economic incentives not to reduce GHG emissions. These incentives could be changed by governmental action, but they are so fundamental that this will prove to be difficult. As illustrated by the problems many EU countries and Canada face in meeting their commitments under Kyoto, politicians would be required to maintain unusually strong resolve as the population learns what the real effects of the measures will be. Under current circumstances, politicians can argue that higher energy prices are a result of the operation of the laws of supply and demand. But if markedly higher prices or energy use restrictions were imposed for the purpose of reducing global warming, they would face a tougher situation.

It is difficult to see why politicians would be willing to force their constituents to adopt unpopular and expensive constraints on their activities, or why many constituents would not pursue every available loophole rather than reduce their welfare and freedom of choice. Grandmothers, for example, may not agree that trips to see their grandchildren on the opposite coast can be dispensed with or priced out of their reach. Global warming has all the psychological characteristics — a long time horizon, uncertainty, and no visible effects to remind people that there is a problem — needed to keep it at a

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modest level of priority, even with a huge public education campaign.

Another fundamental problem with ERD is that it has many of the characteristics of economic planning, such as picking technological and economic winners in advance rather than leaving this to the market. Governments would determine the allowable GHG emissions and seem anxious to dictate the precise means of doing so too. This is already happening, by attempts to legislate the percentage and even the type of renewable energy sources that must be used. Unfortunately, the history of economic planning has shown it to be very unsuccessful and inefficient because of political interference with economic decisions and the inability of governments to finely regulate economic activities they may not understand.

If Hansen's predictions are correct, major catastrophes that would make New Orleans look like a minor event can be expected if the energy balance of the Earth is not stabilized soon. As he points out, events that would reasonably precede his predicted ice sheet disintegration are already happening. But global warming will continue until the energy balance of the Earth is actually stabilized, not when proposals by politicians say it should some time in the future. The balance needed is fairly precise since nature, unlike humanity, does not fudge. The natural systems creating this balance are exceedingly complicated, constantly changing, not well understood, and need fine adjustments — all of which ERD-style world central energy planning is most unlikely to deliver in a timely way, particularly in a world of sovereign states requiring extended negotiations just to agree on what to do let alone actually doing something effective. The experience to date with the Kyoto Protocol suggests what can be expected from continued pursuit of ERD.

Regulatory decarbonization picks technological and economic winners rather than leaving it to the market

A Long Ignored Alternative

Fortunately, there is an alternative to relying on ERD, although it is almost never mentioned by environmentalists and not widely known, much less understood, by the public — solar radiation management, sometimes called stratospheric geoengineering or engineered climate selection. An extensive review of management strategies and currently available alternative technologies for global climate control gives the inescapable conclusion that SRM is the most effective and efficient first step toward solving most of the problems that ERD supporters are concerned about, quickly and easily.

SRM would control temperatures by reducing the radiation reaching the earth from the sun. This would be accomplished by adding particles to the stratosphere to scatter a small, carefully calculated portion of selected wavelengths of incoming sunlight back into space. These particles would naturally slowly drop out of the stratosphere, and would have to be replaced, making relatively rapid adjustments possible. This and similar approaches could be viewed much like any other aerospace project, would cost a fraction of the cost of ERD (roughly 2 to 10 cents per ton of carbon compensated for, not hundreds or thousands of dollars), would need no public involvement once a decision had been made to proceed, would not require the alteration of lifestyles or standards of living, and would provide the flexibility needed to rapidly respond to any warning signs of imminent danger — thus solving all of the problems except ocean acidification. SRM would also avoid the need for extensive economic and energy planning by leaving GHG emission decisions to the private sector, possibly using an institution patterned on the Federal Reserve Board or International Monetary Fund to make periodic adjustments to incoming solar radiation to achieve the desired global energy balance.

As pointed out by Paul Crutzen in 2006 and the National Academy of Sciences in 1992, we have a planet-wide proof of concept: when major volcanic eruptions occur, approximately once a decade, they shoot huge amounts of particles into the air, cooling the planet for several years. One of the best known examples was the explosion of Mt. Tambora in 1815, which caused the "year without a summer" in Europe. The sulfur-containing particles thrown out by eruptions are probably less than optimal. It appears reasonable to believe, however, that humans could improve on nature substantially by refining the type of particles used and minimizing other possible environmental side effects with a little research and development.

SRM would cost less than 10 cents per ton of carbon compensated, rather than hundreds or thousands of dollars through ERD

The reason that SRM cannot solve ocean acidification is that carbon dioxide levels would continue to rise. ERD would help in theory, but given the impossibility of meeting a 98 percent reduction worldwide to prevent the destruction of the world's coral reefs, it may not be a useful solution to this problem either. Fortunately, recent research illustrates that nature has worked out an efficient system for removing carbon dioxide from the seas: fertilizing ocean plankton to

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stimulate them to absorb carbon dioxide (much as plants do) and transport it to the sea floor. Humans have not yet figured out a very efficient way to emulate nature in this regard — seeding the ocean with iron particles has been suggested — but ocean fertilization may be the best current hope, whether under either the ERD or the SRM approach. Given the magnitude of the threat, research on and implementation of geoengineering or other solutions to ocean acidification also needs to become a top priority.

GHG reductions to a level not seen since the Industrial Revolution would be required to solve ocean acidification

Some scientists have suggested a related strategy: using SRM immediately to bring down temperatures during the long period required to reduce GHG emissions, thus avoiding all the adaptation costs and risks of using regulatory de-carbonization alone, while helping the oceans a bit. This appears to be much more expensive than an SRM approach since extensive de-carbonization expenses would be incurred as well, but it would solve Problem 2, the one of most concern because of the possibility of catastrophic effects, in the interim. And it is clearly safer than an ERD approach. Others have advocated using SRM as an insurance policy to back up de-carbonization. The problem with this is that very large adaptation and de-carbonization expenses would be incurred in the meantime. And the world may be totally unprepared to use SRM when an emergency arises unless decision making processes for using it are actively developed and research and development is carried out to optimize the particles and minimize the environmental effects. This is unlikely to happen unless there are real plans to deploy SRM in the immediate future. Even though any nation with the technical and financial resources could implement such a solution on its own, it would be much better to use an international institution to make decisions on how and when such projects should be undertaken and maintained, given their global impact.

Numerous arguments against SRM have been made, such as the risk of unintended consequences. Certainly there is a need for research to better determine the other environmental effects of SRM. But although great care needs to be taken in pursuing SRM, it is not often recognized that ERD is also likely to engender unintended consequences, as it already has by encouraging the destruction of rain forest to increase the production of palm oil as a fuel, for example.

As author Jay Michaelson wrote almost ten years ago there exists an extensive inventory of other arguments for and against SRM, but the issue really turns on a metaphysical question. Even though most GHG control supporters believe that humans are causing major climate changes, they would rather let nature translate human actions in increasing or decreasing GHG emissions into the ultimate effects on climate. Advocates of SRM and other geoengineering approaches, on the other hand, argue that it would be better for humans to determine the desired climatological outcomes (such as lower average temperatures) directly and relatively precisely rather than letting nature, which has no incentive to help humans, sort out the net effects of GHG producing activities. More research could refine geoengineering solutions, but de-carbonization supporters generally oppose it, so there is currently no way to find out what the most refined solutions might be.

Humans have advanced as much as they have in no small part because they have used fossil fuel energy to provide services that once depended on animal and muscle power. The way forward is not to turn back the clock, but rather to search for and implement solutions to each of the problems posed by global climate change using the best engineering and scientific knowledge in the most effective and efficient manner. Unfortunately, the major effect of relying entirely on the hope of drastically reducing carbon emissions may well be to delay the time when effective action is taken to actually solve the three problems. Developing, testing, and deploying refined versions of SRM and determining its environmental effects needs to be a priority.

Any approach to climate change control needs to be able to handle all credible threats. It needs to be flexible, to rapidly adapt to new knowledge or events. It needs to be inexpensive enough to minimize damage to the economy but effective enough to protect us. Although regulatory de-carbonization can play a useful role, this is really a description of SRM or some combination of SRM and regulatory de-carbonization. Building, testing, and deploying a workable SRM capability is the best investment we can currently make to control climate change. Unfortunately, we are not taking this modest step and probably will not as long as we remain fixated on solutions that demand wholesale reform of the world's energy economy. •

The conclusions reported here are based on three technical papers: "Global Climate Change Control: Is there a Better Strategy than Reducing Greenhouse Gas Emissions?" University of Pennsylvania Law Review, June 2007; "Implementation & Utilization of Geoengineering for Global Climate Change Control," Sustainable Development Law and Policy, Winter 2007; and "New Research Suggests that Emissions Reductions May Be a Risky and Very Expensive Way to Avoid Dangerous Global Climate Changes," http://yosemite.epa.gov/EE/epa/ord.nsf/WPNumberNews/2007-07.

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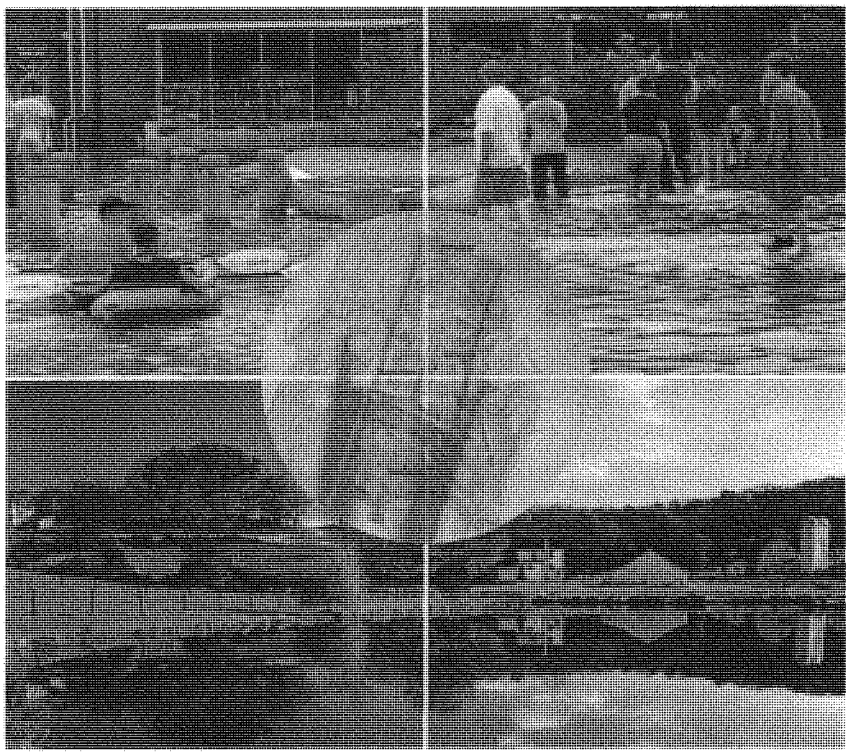
CHESAPEAKE BAY FOUNDATION
Saving a National Treasure

REPORTS



Climate Change and the Chesapeake Bay: Challenges, Impacts, and the Multiple Benefits of Agricultural Conservation Work

EXECUTIVE SUMMARY

Scientists agree: Climate change is here, and across the region, we are seeing the effects. Rising temperatures are inhospitable to vital underwater grasses and stress fish populations from striped bass in the main Bay to brook trout in Pennsylvania's coldwater streams. Sea level rise inundates many of the Bay's iconic islands—islands that until recently supported thriving communities.

Climate change adds new challenges to an ecosystem already stressed by pollutants, population growth, and increasing development.

Fortunately, the situation is not without hope. The fight to reduce the greenhouse gases that cause climate change is not unlike the challenge we face in cleaning up and restoring the Chesapeake Bay and its rivers and streams. And many of the solutions are the same.

The Bay's watershed states have identified a list of cost-effective agricultural conservation practices that must be implemented to achieve the pollution reductions necessary to remove the Chesapeake Bay and its tributaries from the nation's "dirty waters" list. And, as a recent Yale study demonstrates, many of these agricultural practices will also sequester substantial amounts of carbon from the atmosphere.

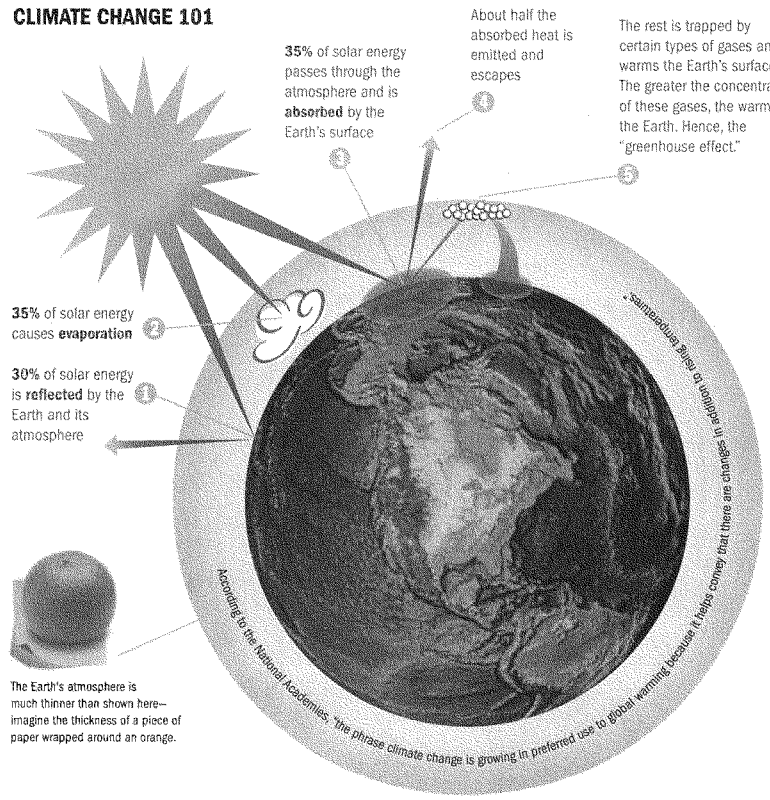
Using information on the number of acres of land, watershed-wide, expected to be placed under several agricultural best management practices, including cover crops, riparian buffers, rotational grazing and no-till farming, the Yale study estimated the amount of carbon dioxide that would be removed from the atmosphere over a 15 year period.

The result? Approximately 4.8 million metric tons of carbon dioxide would be sequestered annually—the equivalent of mitigating the carbon dioxide emissions from residential electricity use across Delaware. The conclusion is clear: Protecting the Bay also helps fight climate change. Accordingly, CBF is working with partners across the watershed to secure state and federal funding for agricultural conservation practices and technologies to reap the multiple benefits of these practices.

Clearly, however, these actions alone will not turn the tide.

To avoid the more catastrophic effects associated with climate change, scientists have estimated we need to reduce greenhouse gas emissions worldwide by 50 to 80 percent over the next 50 years. Transportation, commercial building operations, and residential energy use account for almost two-thirds of greenhouse gas emissions, so a comprehensive plan must also address these sources, all of which will also benefit water quality. The technology is there, as is the knowledge. With careful planning, sustained commitment, aggressive action, and political will, the Bay—and the planet—can be saved.

CLIMATE CHANGE 101



U.S. Greenhouse Gas Emissions by Gas, 2005

(Percentages reflect amounts of gases adjusted for their relative potency.)

Carbon Dioxide (CO_2) — 84%
CO_2 is the least potent greenhouse gas, but it is by far the most abundant, and so remains of primary concern.

Methane (CH_4) — 7%
Methane is more potent than CO_2, trapping **20-25 times** more solar energy.

Nitrous Oxide (N_2O) — 7%
Nitrous Oxide traps **300 times** more solar energy than CO_2.

Other (like chlorofluorocarbons) — 2%

Major Sources of Greenhouse Gases: motor vehicles, energy generation, deforestation, livestock, agriculture

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CLIMATE CHANGE AND THE CHESAPEAKE BAY: CHALLENGES, IMPACTS, AND THE MULTIPLE BENEFITS OF AGRICULTURAL CONSERVATION WORK

Scientists agree: Climate change is here, and it is affecting local rivers, streams, and the Chesapeake Bay.

According to the Intergovernmental Panel on Climate Change (IPCC), there is near-universal consensus about the scientific reality and probable impacts of climate change. Further, these scientists confirm what has long been debated: Human activity is to blame. In fact, human actions are accelerating numerous phenomena, from higher air and water temperatures and rising sea levels to the unpredictable weather patterns and increased storm intensity expected as the result of increasing emissions of greenhouse gases.

In the Mid-Atlantic Region, scientists predict a wide range of climate change-associated effects—from changes in agricultural and forest production to degraded coldwater fisheries and the influx of more invasive plants. One likely outcome: the loss of underwater grasses, like eelgrass, that support species as diverse as the iconic blue crab and the human communities that depend on them.

Some experts, like Dr. Donald Boesch, President of the University of Maryland Center for Environmental Science, theorize that due to the relatively fragile nature of the Chesapeake Bay's current condition and the region's sinking shorelines, the Bay will be particularly vulnerable to the temperature increase and sea level rise associated with global climate change.

Temperature Increase

According to the National Climatic Data Center, global annual temperatures are now about one degree Fahrenheit (F) warmer than at the start of the 20th century. This warming has accelerated over the past 30 years, increasing approximately three times faster than previous century-average trends. The IPCC estimates a further increase in average temperatures of 2.5 to 10.4 degrees F before 2100.

Among other impacts, higher air temperatures in the Chesapeake Bay region mean a rise in water temperatures, with potentially devastating ecological consequences. Warmer water has less capacity to hold dissolved oxygen, and dissolved oxygen is critical for most life in the Bay, its rivers, and its streams. Thus, higher temperatures may exacerbate the Bay's dead zone, potentially expanding both the size and the duration of oxygen-deprived areas in the Bay.

Changes in water temperature can also affect the distribution and health of aquatic species in the Chesapeake. For instance, adult striped bass, also known as rockfish (a $6.6 billion fishery), try to avoid water warmer than about 76 degrees F by finding refuge in the cooler temperatures of deeper water. During the summer, however, rockfish face what scientists call "temperature-dissolved oxygen squeeze," when dissolved oxygen concentrations in these waters drop past the point where adult rockfish can survive.

With predictions of higher water temperatures and expanded dead zones, rockfish will be increasingly squeezed, forced to live in uncomfortably warm water in order to "breathe."

Such stress can affect the health of the fish by changing their feeding habits or making them more susceptible to disease.

Sea Level Rise

Worldwide, the IPCC predicts that sea level will rise between 8 inches and 2 feet by the end of this century. Many scientists consider those estimates to be conservative; evidence is mounting that ice caps and glaciers are melting at accelerated rates. If that continues, says Dr. Boesch, apparent sea level rise could be as high as three to four feet in the Bay region by the end of the century.

The Chesapeake Bay and its tributaries share 11,000 miles of shoreline and coastline, including some of the most valuable areas in the country. Although sea level rise will affect many parts of the world, the Bay region may suffer even more. Why? Because, even as waters rise, much of the area is actually sinking due to geological processes that began during the last ice age. This combination of processes has resulted in approximately one foot of net sea level rise in the Chesapeake Bay over the past 100 years—a rate nearly twice that of the global historic average. As a result we are losing Tangier Island, Smith Island, and many other low-lying lands around the Bay.

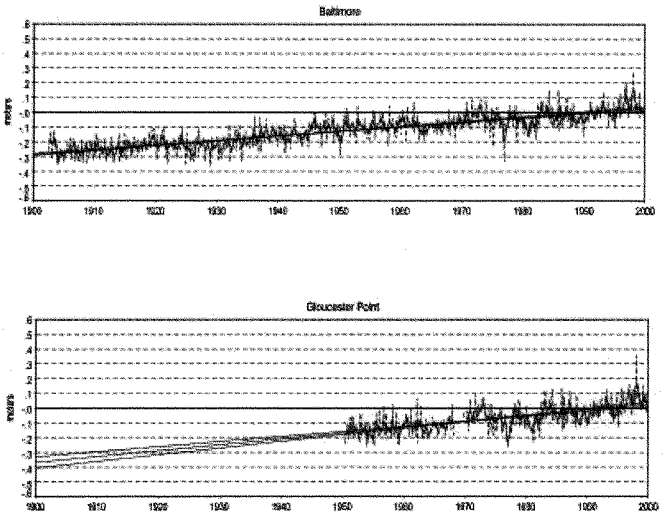
Thousands of acres of environmentally-critical tidal wetlands are now unable to trap sediments fast enough to keep pace with rising water levels. In the future, the combination of sea level rise, relatively flat topography, and subsiding land mass could make the Mid-Atlantic region—and the people who live here—particularly vulnerable. (Rygel, Yarnal, Fisher. 2005).

Such scenarios have clear and sobering implications for restoration efforts across the watershed.

The impacts of climate change may well impede progress toward meeting Bay restoration and water quality goals, and make it more of a challenge to restore its health. The prospects appear grim.

But the situation is not without hope: personal and public commitment, existing knowledge, and new technologies can change the tide. In fact, the fight to reduce greenhouse gas emissions is not unlike the challenge we face in cleaning up and restoring the Chesapeake Bay and its rivers and streams. And many of the solutions are the same.

Mean Sea Level Trends for Selected Locations in the Chesapeake Bay Watershed
(Source: NOAA)



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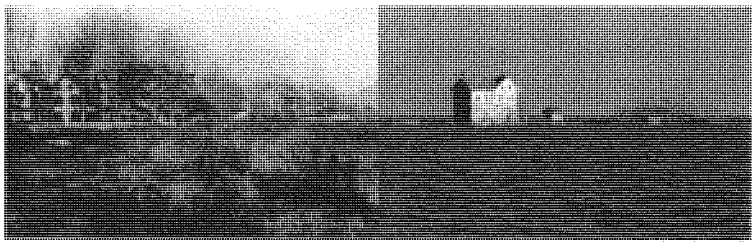
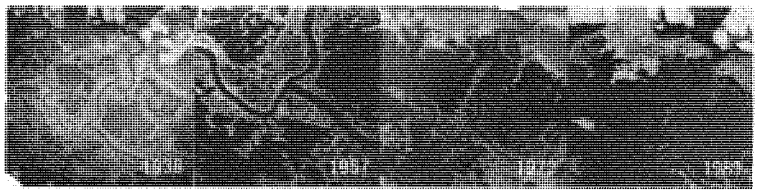
The Bay's Disappearing Lands

Island	Previous Acreage		Recent Acreage		% Lost	Notes
Sharps	890	(1660)	0	(1962)	100	Drowned in 1962
Poplar	1,400	(1670)	125	(1990)	91	Abandonment in 1930
St. Clements	400	(1634)	40	(1990)	90	Abandonment in 1920s
Barren	700	(1664)	250	(1990)	64	Abandonment in 1916
Holland	217	(1668)	140	(1990)	35	Abandonment in 1992
Smith	11,033	(1849)	7,825	(1987)	29	Submerging
Hoopers	3,928	(1848)	3,085	(1942)	21	Submerging
Bloodsworth	5,683	(1849)	4,700	(1973)	21	Submerging

(Source: Johnson, Z., 2000)



Taken in the late nineteenth century, the photo at left shows Holland Island, in southern Dorchester County, Maryland. Once spanning over five miles, this island supported a post office, a church, a schoolhouse, and several stores. As the devastation of erosion became apparent in the early 1900s, many residents of Holland Island moved their homes to Cambridge and other towns. Today, most of the remaining 100 acres are marshland. Only one structure remains.



Seven thousand acres of marsh land have been lost since the establishment of the Blackwater National Wildlife Refuge in Maryland—due to a combination of sea level rise, land subsidence, and the invasive, marsh-grass eating rodent known as nutria. These losses are continuing (at a rate of approximately 150 acres per year) and in the future, widespread inundation of marsh lands is expected across the watershed. Besides serving as important fish and wildlife habitat, wetlands serve a critical role in protecting shorelines and nearby lands from the effects of flooding and erosion. Strategies to address climate change must include actions that minimize the loss of these critical buffers.

July 2007

THE ROLE OF AGRICULTURE IN MITIGATING GREENHOUSE GASES

Many of the steps needed to reduce water pollution will also lead directly to reductions in greenhouse gases and help minimize the effects of rising sea level and higher temperatures.

Dual Benefits of Reducing Nitrogen Pollution in the Chesapeake Region

Nitrogen pollution contributes to the formation of frequent oxygen-deprived "dead zones" in the Chesapeake Bay and its tributaries, a condition which—in addition to killing aquatic life —can actually contribute to greenhouse gas generation by the Bay itself.

Globally, estuaries emit approximately one third of the world's oceans' net emissions of nitrous oxide. In the few places where it has been studied, nitrogen pollutant loads to estuaries have been shown to contribute to increased nitrous oxide emissions (Matson and Ortiz-Monasteno, 2003). Similarly, estuarine production of methane also increases under low-oxygen conditions due to bacterial activity, so the Bay, in its overloaded and degraded state, is actually contributing to climate change.

Watershed-wide, about one-third of the nitrogen pollution in the Chesapeake comes from the air, much of it in the form of nitrogen oxides formed from the combustion of fossil fuels. Thus, personal choices to conserve electricity or drive more fuel-efficient vehicles, along with state and national efforts to increase the use of renewable energy sources also reduce emissions of nitrogen oxides. Each of these actions has the added benefit of reducing carbon dioxide as well.

Environmental strategies focused on reducing one pollutant (nitrogen) have the potential to address multiple problems. The conclusion is clear: Protecting the Bay also helps fight climate change.

Agricultural Conservation and the Fight to Slow Climate Change

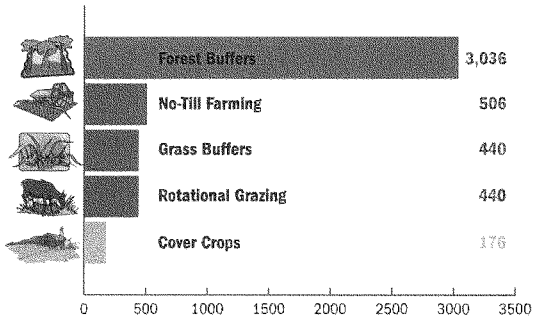
Implementation of agricultural conservation practices, while often overlooked in policy discussions about reducing greenhouse gases, promises to be doubly beneficial for climate change and water quality in the Bay region and beyond.

The Chesapeake Bay watershed states have already defined agricultural conservation as a key tool to achieve the pollution reductions necessary to remove the Chesapeake Bay and its tributaries from the Clean Water Act's "dirty waters" list. As part of the Chesapeake 2000 Agreement—a pledge to cut the amount of nitrogen, phosphorus, and sediment pollution discharged into the Bay and its rivers—those watershed states (Pennsylvania, Maryland, Virginia, Delaware, West Virginia, and New York) and the District of Columbia have each developed river-specific "Tributary Strategies" to achieve targeted pollution reduction goals.

Region-wide implementation of these plans' agricultural components would reduce the excess nitrogen entering the Bay by nearly 65 million pounds annually—approximately 60 percent of the reduction needed to restore the Bay and its tributaries. As a recent study conducted by graduate students at the Yale School of Forestry and Environmental Studies (Devooght, Caldwell, and Jewell 2007) demonstrates, many of these practices will also sequester substantial amounts of carbon from the atmosphere.

Carbon Sequestration Rates of Selected Agricultural Conservation Practices

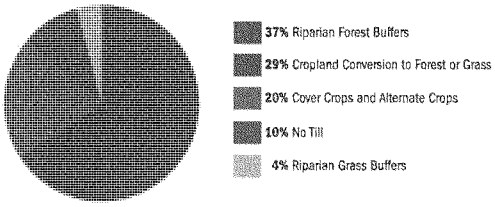
(Pounds of Carbon per Acre per Year)



Carbon sequestration refers to the net removal of CO_2 from the atmosphere into long-term or permanent terrestrial 'pools': living (trees or grasses; roots and microbes in the soil), stored in products with long lives such as lumber, or contained as soil carbon. An enormous amount of carbon is stored in the soil and detritus on the soil—the remnants of plants and trees. **Agricultural practices can help increase these carbon pools.** For example, planting riparian buffers results in carbon sequestered in trees or grasses. And although traditional farming techniques, such as plowing, reduce soil carbon levels by allowing CO_2 to be released into the air, many farmers in the Bay region practice conservation tillage, where plowing and hoeing are replaced with either no, or shallow, tillage that exposes less soil to erosion—and less carbon to the atmosphere.

Using data from the Chesapeake Bay Program on the number of acres of land, watershed-wide, expected to be placed under selected agricultural best management practices, or BMPs, the Yale study estimated the total amount of carbon dioxide that would be removed from the atmosphere over a 15-year period. The study included only those conservation measures for which there was sufficient scientific evidence for reliably estimating carbon sequestration rates: conservation tillage, use of winter cover crops, grassed and forested riparian buffers, rotational grazing, and conversion of cropland to forests or open space.

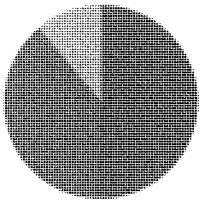
The Yale analysis found that watershed-wide implementation of selected agricultural BMPs on Bay region farms would sequester approximately 4.8 million metric tons of carbon dioxide annually, over a 15-year period (for details see www.cbf.org/yalestudy). One metric ton equals 2,205 pounds.



Rotational Grazing was not included because the contribution was less than 1%.

It is worth noting that with the exception of winter cover crops, these practices are included in the suite of eligible "offset projects" by the Chicago Climate Exchange, North America's only active voluntary, legally-binding, integrated greenhouse gas trading system (http://www.chicagoclimatex.com/)

Put this number into perspective: Implementing these practices could mitigate, or balance out, the carbon dioxide emissions of nearly three quarters of a million SUVs (approximately 786,438 Hummers traveling an average of 12,000 miles annually), or the entire statewide residential electricity use of either New Hampshire or Delaware (electricity use estimated using state emission factors for greenhouse gases and residential electricity sales. Energy Information Administration). Essentially, helping Bay region farmers adopt these measures could mitigate the residential electricity use of an entire state.



On a state-by-state basis, the greatest carbon sequestration benefits would be accrued in Virginia—approximately 2.3 of the 4.8 million metric tons. This large share is due to the prevalence of forest buffers and restoration programs in the Commonwealth's Tributary Strategies. In Pennsylvania and Maryland, carbon benefits would come from a broader combination of conservation practices. All of these activities also improve water quality, aquatic life, and healthy habitats across the local rivers and streams of the Chesapeake.

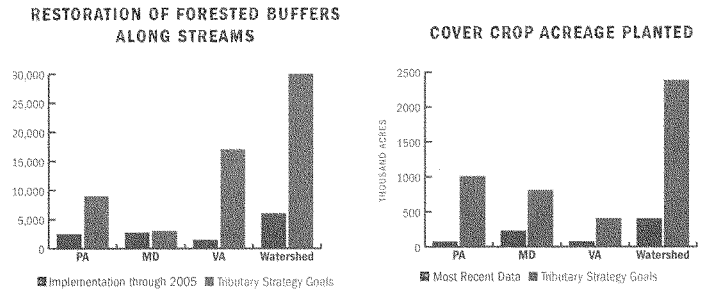
Additional Climate Change Benefits of Saving the Bay

CBF believes the Yale study's estimate to be conservative because it calculated only the carbon sequestration benefits of a portion of the agricultural practices in the Tributary Strategies. Other programs that benefit water quality and mitigate greenhouse gases were not included because of insufficient quantitative information on their benefits. These include:

- Adoption of enhanced nutrient management practices that will result in less fertilizer use. This will lead to reduced emissions of nitrous oxide, a potent greenhouse gas, by as much as 30 to 40 percent (Council for Agricultural Science and Technology, 2004).
- Improved manure management: Manure-to energy projects such as anaerobic digesters will capture methane and use it as an energy source that displaces fossil fuels.
- Precision feeding: Enhanced animal feed quality and metabolic efficiency in meat and milk production can reduce methane production by livestock.
- Minimizing the use of farm machinery: Practices such as conservation tillage and no-till farming can reduce fossil fuel consumption and its associated carbon dioxide emissions by up to 70 percent (West and Marland 2002).

In addition, agriculture can help reduce energy dependence on fossil fuels by providing new sources of energy (for example: ethanol made from corn or switchgrass, or biodiesel made from soybeans). (For more detail, see cbf.org/ethanol).

Implementing the agricultural practices called for in the Tributary Strategies will create multiple environmental benefits—on the local level by cleaning up the Bay, its rivers, and its streams, and globally by mitigating greenhouse gases. Across the watershed, CBF is working with other stakeholders to secure the funds needed to achieve this goal.



Although the Bay state governments have taken some important steps toward funding agricultural conservation practices, we are far from reaching the levels necessary to achieve Chesapeake Bay water quality goals. The charts above compare state-by-state implementation rates to Tributary Strategy goals for two key agricultural programs.
(Source: Chesapeake Bay Program)

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Progress around the Watershed

Agriculture has much to offer in helping to reduce greenhouse gas emissions to the atmosphere, while at the same time improving water quality and the sustainability of the agricultural sector. Of course, much more needs to be done in this region if we are to achieve the reductions that scientists say are necessary to avoid catastrophic climate change. Thankfully, some smart steps are already taking place.

PENNSYLVANIA

Governor Rendell recently doubled the Commonwealth's government purchase of "green" electricity from renewable sources from 10 to 20 percent, in addition to significantly increasing investment in infrastructure upgrades to support production and distribution of alternative fuels.

Pennsylvania implemented the "Clean Vehicles Program" which requires new cars or light-duty trucks to meet stringent California emissions standards for carbon dioxide and other pollutants.

VIRGINIA

Governor Kaine issued an Executive Order that established "green building standards" for new and renovated state government buildings, ordered all agencies to reduce their annual cost of nonrenewable energy purchases by 20 percent by 2010, and created an Energy Policy Advisory Council.

Virginia passed legislation that requires the development of a comprehensive 10-year Energy Plan by July 2007, joins Maryland in establishing a solar energy grant program, and allows Virginia consumers to receive a tax credit valued at 20% of the cost of certain energy efficient products.

MARYLAND

Governor O'Malley issued an Executive Order to create a Maryland Commission on Climate Change and committed to achieving a 15 percent reduction in residential energy use by 2015.

Maryland passed a "Clean Cars Act" which requires new cars or light-duty trucks to meet stringent California emissions standards for carbon dioxide and other pollutants, and approved the "Healthy Air Act" which commits Maryland to joining the Regional Greenhouse Gas Initiative, a multi-state partnership that requires reductions in green- house gas emissions from power plants.

D.C.

Mayor Fenty signed onto the U.S. Conference of Mayors Climate Protection Agreement, committing the District to meet the Kyoto Protocol's targets for reducing greenhouse gas emissions.

The District's newly formed Department of the Environment includes a "Sustainable Solutions Division" whose self-stated vision is to "power the District of Columbia with Green," and the Reliable Energy Trust Fund supports a variety of energy efficiency and renewable energy programs.

CHESAPEAKE 2000

The Chesapeake 2000 Agreement, if fully implemented, would remove approximately 110 million pounds of nitrogen pollution from the Bay annually and help mitigate the Bay region's output of CO_2.

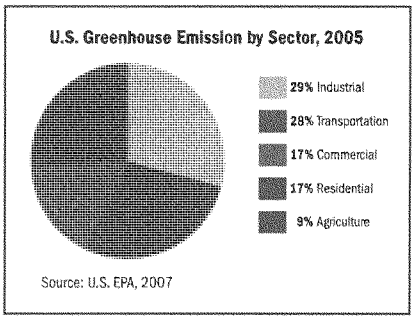
July 2007

NEXT STEPS

To avoid the more catastrophic effects associated with climate change, scientists believe we need to stabilize greenhouse gas concentrations in the atmosphere. Doing so means reducing emissions of these gases worldwide by 50 to 80 percent over the next 50 years. Recent reports issued in Maryland and Pennsylvania have identified state specific greenhouse gas reduction targets consistent with this goal, and outlined policy recommendations for achieving them (Environment Maryland, 2007; Pennsylvania Environmental Council, 2007).

Environment Maryland's "Blueprint for Action" recommends several policy options to reduce carbon dioxide emissions by approximately 30 million metric tons, representing a 23% decrease from 2006 emissions in Maryland. Similarly, the Pennsylvania Environmental Council's "Climate Change Road Map" describes a comprehensive set of policy options that could be implemented to reduce carbon dioxide emissions in Pennsylvania by 25% from 2000 levels, a reduction of approximately 75 million metric tons.

Given the need for such drastic cuts and the multitude of greenhouse gas sources, a comprehensive response to climate change will require a portfolio of solutions: Agriculture is only one. Transportation, commercial building operations, and residential energy use account for almost two-thirds of greenhouse gas emissions, so a comprehensive greenhouse gas mitigation plan must also address these sources, all of which will also benefit water quality.



As highlighted in the reports by Environment Maryland and Pennsylvania Environmental Council, policy options should include:

Transportation:

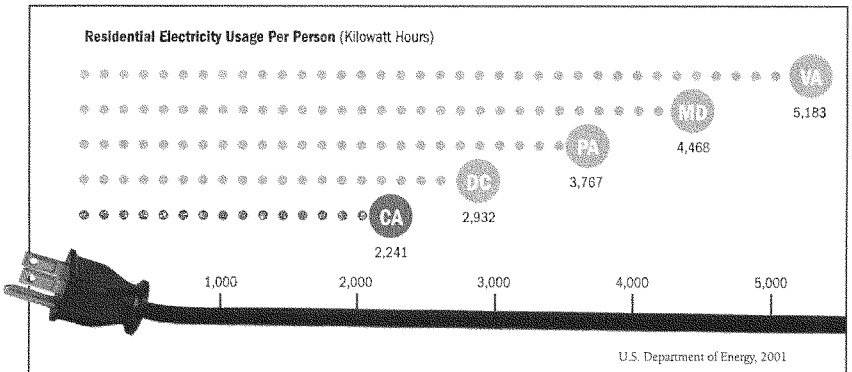
- REDUCE reliance on automobile travel through "commuter choice" programs like mass transit, carpooling, and telecommuting that expand the options available to commuters;
- PROMOTE smart growth and CURB sprawling development by building more compactly, in already urbanized areas; and
- CONSTRUCT modern and efficient transit systems.

Buildings:

- PROVIDE incentives to build energy-efficient "green" office buildings and improve energy efficiency in older ones; and
- PLAN and ZONE to promote commercial development inside existing communities and close-in locations, instead of sprawling across the Bay region's remaining rural, undeveloped, "greenfields."

Residential Energy Use:

- IMPLEMENT aggressive energy efficiency programs, including insulation, window replacement, the use of compact fluorescent lighting, and energy conservation; and
- INCREASE the amount of electricity that comes from renewable sources.



U.S. Department of Energy, 2001

Aggressive energy programs and increased renewable energy sources could significantly reduce our carbon dioxide emissions. Per person, Virginia and Maryland use more than two times as much electricity as residents of California.

The long-term campaign to reduce greenhouse gas emissions and avoid the more devastating effects of climate change will be fought on many fronts. Fortunately, as highlighted by the Yale report, efforts to support clean water, including agricultural conservation programs, are vital tools in slowing climate change. CBF calls on our local, state, and federal governments to aggressively pursue funding for, and implementation of, existing and new agricultural conservation practices and technologies. Clearly, however, these actions alone will not turn the tide.

CBF also calls on cities, states, the federal government, and individuals to rethink our national energy policy, increase partnerships between farmers and businesses, take advantage of opportunities presented by transportation and land use planning, adopt more efficient technologies, and undertake fundamental shifts in the choices each one of us makes, every day, in our businesses and homes. With careful planning, sustained commitment, aggressive action, and political will, the Bay—and the planet—can be saved.

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Regional Impacts of Climate Change

Higher Air Temperatures in Baltimore, Maryland

It is a hard reality to accept: While climate change will impact everyone, the region's elderly and disadvantaged will likely face the most devastation.

According to the World Health Organization, recent heat waves in Europe have been linked to significant numbers of human deaths. A preliminary analysis of the 2003 heat wave in Europe estimated that it caused higher than average mortality rates in Great Britain (2,045), Portugal (2,099), and France (14,802).

Although quantified predictions are difficult, it is clear that rising atmospheric temperatures in this region may have devastating effects, particularly in urban areas like the city of Baltimore. An EPA report states that a warming of three degrees F could increase heat-related deaths by 50 percent—from the current average of 85 to 130—mostly affecting the elderly. In addition, Baltimore has some of the worst air quality in the country, regularly violating air quality standards for ozone (smog) and fine particulate matter (soot). High temperatures exacerbate this problem and the human health effects associated with air pollution. The possible result: increased incidence of asthma, reduced lung function, and premature death.

Fish Kills on the Shenandoah River, Virginia

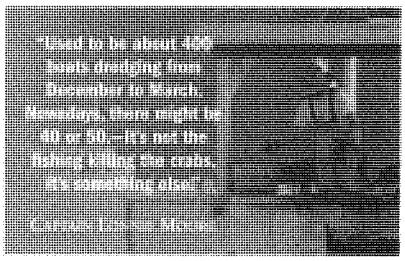
In 2005 alone, nearly 80% of adult smallmouth bass died in more than 100 miles of the South Fork Shenandoah River in Virginia. A preliminary study estimated a loss of $686,000 in retail sales and revenues (Papadakis 2006).

Large numbers of smallmouth bass and redbreast sunfish in Virginia's Shenandoah River watershed have died in the last four years. The causes of the Shenandoah fish kills remain unknown, but scientists have speculated that increased water temperatures may be playing a role—either by causing stress to the fish, making them more susceptible to infection, or providing a more favorable environment for the pathogens that attack them. Bacterial skin and gill lesions are particularly prevalent on many dying fish.

Researchers at James Madison University have documented a water temperature increase of as much as five-degrees Fahrenheit over the past few decades in the Shenandoah basin (Brown, Downey and Benzing, 2007). The cause of the temperature increase is not necessarily linked to global warming, but as the region's scientists continue to search for the causes of these mysterious fish kills, we are left to wonder whether the Bay region will be seeing more of these events as the climate continues to change.

Eelgrass, Crabs, and the Economy and Culture of the Chesapeake Bay

Eelgrass—an underwater grass found in the mid-to-lower parts of the Bay and a vital link in the ecological web of the estuary—experienced a major die-off in 2005. Dr. Robert Orth at the Virginia Institute of Marine Science (VIMS) and other underwater grass researchers concur: The die-off was due to higher water temperatures. Negative impacts of dramatic grass loss may include degradation of critical habitat for blue crabs and other aquatic species, and economic consequences for the people and industries that depend on them.

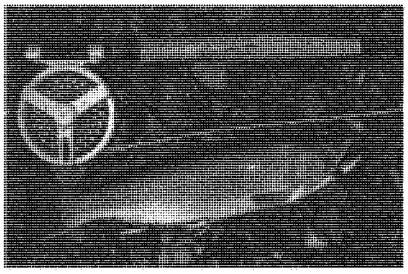


July 2007

Underwater grasses provide blue crabs refuge from predation and—particularly critical for young crabs—cover during molts. Large numbers of juvenile crabs depend on the shelter of the eelgrass beds in Tangier Sound as they move from offshore waters to the upper Bay. (VIMS scientists have found that young crabs are 30 times more prevalent in grass beds than on barren bottom.) In 2006, eelgrass beds remained few and sparse in the Bay, and the 2007 winter crab survey indicated that the number of young-of-the-year crabs—those less than two inches across—was among the lowest observed since the survey began in 1990.

Rising Water Temperatures and Pennsylvania Brook Trout

According to the Pennsylvania Fish and Boat Commission, nearly two million people go fishing in Pennsylvania each year, contributing over $1.6 billion to Pennsylvania's economy. The Susquehanna River basin contains some of the best fishing in the world. Cold-water species, especially brook trout, once thrived in all of the Susquehanna basin's rivers, streams and brooks. Brook trout—sensitive to stream temperatures for survival and reproduction—thrive in water temperatures cooler than 65 degrees. Although the fish can tolerate brief periods of warmer water (up to 72 degrees F), exposure to temperatures warmer than 75 degrees is usually lethal, even if for only a few hours.



Even a small increase in stream temperatures could cause the disappearance of brook trout from Pennsylvania waters.

Today, healthy brook trout habitat and populations exist in only a fraction of the fish's historical range. Despite significant public and private efforts to restore them and their habitat, these remaining populations are seriously threatened by climate change. If the brook trout disappear, what will replace them and the economic engine they drive?

Sea Level Rise Around Hampton Roads, Virginia

A 2005 report by the Center for Integrated Regional Assessment evaluated the relative impacts of sea level rise on Hampton Roads' communities of varying economic health. Compounding the challenges faced by low-lying areas in Hampton Roads is the loss of living, or natural shorelines, and threats to remaining wetlands. While healthy shorelines and wetlands can not stop storms from occurring, they can play a role in protecting communities from the worst storm surges and floods.

A combination of current demographic modeling and projected sea level rise suggests that hundreds of thousands of people in the Chesapeake region could fall victim to serious floods, and these storms are likely to cause the most damage to socially vulnerable populations within the region. The report defines areas within Hampton Roads and with high "numbers of children and elderly, and with a high number of mobile homes" as vulnerable. By a wide margin, these at-risk communities are the most likely to face severe flood and storm damage. Additionally, these storms—which are also predicted to increase in intensity—will not only increase demands on emergency services and rescue facilities in these areas, but literally flood those facilities as well. Essentially, those with the fewest resources to recover from a catastrophic storm will be the hardest hit.

Save the Bay. Save the Planet.

How Can I Make a Difference?

Many of the things we do to help save the Bay and its rivers and streams will also help reduce the greenhouse gases that cause climate change. Simple, everyday choices can have a powerful cumulative effect. Most of us leave the biggest carbon footprint with our cars. Every gallon of gasoline we burn spews about 20 pounds of carbon dioxide into the atmosphere. Car exhaust is also one of the fastest growing sources of nitrogen pollution to the Bay. And, since power plants are huge producers of both CO_2 and nitrogen pollution, anything we do to use less electricity at home will also have a positive effect.

Begin at Home	Good for the Bay	Good for the Planet
❑ Purchase fluorescent light bulbs for your home.	✔	✔
❑ Install motion sensors to turn off lights when you don't need them.	✔	✔
❑ Use energy-efficient appliances. (Look for the Energy Star label.)	✔	✔
❑ Insulate your hot water heater with an insulated blanket.	✔	✔
❑ Ask your energy company to switch your home to "green energy."	✔	✔
❑ Turn down your heat or air conditioning and hot water heater.	✔	✔
❑ Save trees, fuel, and postage by paying your bills online.	✔	✔
❑ Clean or replace your air conditioning filter as recommended.	✔	✔
❑ Install low-flow shower heads to reduce water usage.	✔	✔
❑ Plant trees near your home to provide shade in summer.	✔	✔
❑ Only run your dishwasher when there is a full load.	✔	✔
❑ Insulate walls and ceilings, and caulk around doors and windows.	✔	✔
Economize Your Car		
❑ If you need a new car, choose one with excellent fuel economy.	✔	✔
❑ Carpool, bike, or take mass transit when you can.	✔	✔
❑ In city traffic, roll down your windows to keep cool in warm weather.	✔	✔
❑ Improve your gas mileage by keeping your tires properly inflated.	✔	✔

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Maryland
Philip Merrill Environmental Center
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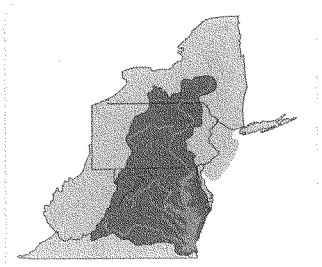
Annapolis, MD 21403
410/268-8816
410/269-0481 (from Baltimore metro)
301/261-2350 (from D.C. metro)

Pennsylvania
The Old Water Works Building
614 North Front Street, Suite G
Harrisburg, PA 17101
717/234-5550

Virginia
Capitol Place
1108 East Main Street, Suite 1600
Richmond, VA 23219
804/780-1392

Web site: cbf.org
E-mail: chesapeake@cbf.org
Membership information: 888/SAVEBAY

CHESAPEAKE BAY WATERSHED



The Chesapeake Bay's 64,000 square mile watershed covers parts of six states and is home to more than 17 million people.

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REFERENCES:
For a full list of references, go to cbf.org/climatechange.

July 2007

CHESAPEAKE BAY COMMISSION
Policy for the Bay• www.chesbay.state.va.us

Climate Change and Chesapeake Bay: A Summary of Management Issues

Introduction

According to the International Panel on Climate Change, an overwhelming number of observations indicate that the world is warming, the climate system is changing and that these changes will be unstoppable for centuries. These changes pose a significant threat to the ecological health of the Chesapeake Bay and the economy of the surrounding communities, yet much research remains to fully understand the extent of that threat.

In the efforts to restore Chesapeake Bay and other estuaries around the nation and world, the focus has been on historical data. What were the conditions of the water quality and living resources of the estuary over time? What were the factors that led to a degradation or improvement to the estuary? Using empirical evidence of the effect of land management practices or pollution-reducing technologies already established, what future improvements can be expected?

In light of mounting evidence of global climate change, we may no longer be able to rely solely on observations of the past when predicting the outcome of restoration activities. In fact, application of future climate change variables should become a standard practice in the development and adoption of public policy regarding restoration. This paper will summarize the stages in decision-making where these variables should be applied and the information gaps that must be filled before a meaningful assessment of climate change impacts can occur.

Decisions ripe for climate change input

A recurring theme of the Chesapeake restoration effort is "we know what needs to be done." Decades of research, modeling, and on-the-ground efforts have demonstrated the practices and technologies that must be put in place to achieve desired water quality standards, and significant resources have been and will be dedicated to meeting those standards. However, the assumptions underlying those goals include historical data on precipitation, temperature, Bay salinity, and atmospheric CO_2, among others. Each of these factors can influence the ecology of an estuary and its watershed and each of these factors are affected by climate change.

In the near term, the effects of climate change may be minimal, but we are not sure. Some experts caution that that increased intensity and frequency of hurricanes and tropical storms may bring ruin to parts of the Bay sooner than we think (e.g. Isabel). Regardless, the longer it takes to reach water quality goals, the more influence climate change will have on our efforts. It is, therefore, critical to maximize the restoration progress we can make in the next few years.

Over the long term, it will become increasingly important for climate change factors to be incorporated into the assumptions that underlie Tributary Strategies or TMDL plans, as well as

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plans to maintain progress that has been achieved (e.g. changes in precipitation frequency and amount should be considered when evaluating the long-term efficiency of a land-based best management practice). Similarly, such strategies or plans should incorporate a mechanism to adapt to changing climatic indicators. In addition to Tributary Strategies or TMDL plans for the watershed, living resource management plans should also be designed to account for these factors.

The key to integrating these factors into planning efforts includes two parts. The first is the extent to which monitoring can be used to reliably detect indicators of climate change and attribute their causes, much like what is currently in place for water quality. The second is to communicate this monitoring information in a useful manner to decision-makers. As local, state, and federal partners look to increase their investment in restoration activities, the time to develop climate change monitoring and communication tools is now.

Data gaps requiring further research

Estuaries, by nature, are extremely complex ecosystems. This, in turn, makes the influence of climate change on estuaries that much more difficult to identify and quantify. The effects of land use, freshwater flow, forcing from the open ocean, and direct contact with the atmosphere will interact with each other in an estuarine environment. Thus, research conducted exclusively on land or at sea has limited applicability to an estuary. Unfortunately for the Chesapeake, most climate change research is not specific to the Bay region. However, there are currently at least a dozen federal and academic partners[1] in the watershed currently engaged in climate change research, albeit without a strategic plan for prioritization of research projects or sharing of information.

Consequently, significant data gaps remain regarding the influence of climate change on Chesapeake Bay and its watershed. When filled, this information will be extremely helpful in determining the future steps of our restoration efforts.

1. **How do increases in sea level, storm surge and shoreline development affect the vulnerability of coastal areas and what are appropriate management strategies?**
   The Chesapeake Bay region is the third most vulnerable area in the nation to sea level rise induced by climate change, trailing only Louisiana and Southern Florida in national assessments. The effects of sea level rise and storm surge induced by climate change include shoreline erosion, coastal flooding, salt water intrusion and freshwater resources, and inundation of some coastal areas. These predicted changes would significantly affect low-lying land areas, islands, coastal wetlands and beaches in the Chesapeake Bay. The Bay has risen approximately one foot in the last century, nearly twice the global average, due to the combination of climate change and regional land subsidence. Given the current and predicted rates of sea level rise, many low-lying areas will be dominated by open water by 2050.

[1] Federal: NSF, NOAA, EPA, USGS, USDA/CSREES, USDA/USFS; Academic: PSU, UMD, VIMS, VA Tech, Cornell, SERC

2. **Are there adequate public institutional and private sector mechanisms in place to address the vulnerability and cost to restore the Chesapeake's built and natural infrastructure to climate change-induced sea level rise?**
   The threats posed by climate change have had serious ramifications for insurers and the insured in the Chesapeake region. In 2005, the Ceres investor coalition reported that U.S. insurers have seen a 15-fold increase in insured losses from catastrophic weather events (those over $1 billion in damages) in the past three decades. As a result, insurers are starting to change their risk-assessment models to reflect future climate change scenarios instead of past weather patterns. For example, rather than identify individual policies that were of higher risk, All-State Insurance recently ceased issuing new policies in a large portion of the Chesapeake region.

   Scientists have determined that restoration of New Orleans' wetlands "hurricane buffer," lost during Katrina and over past decades, will cost an estimated $14 billion to restore. The price tag to restore Chesapeake wetlands and other aquatic resources is unknown.

3. **How many increases in frequency and volume of storm events impact combined sewer overflow systems (CSOs)?**
   If, as it has been shown in other areas, CSOs in the Bay watershed have been designed based on historical precipitation rather than expected future precipitation levels, should more overflow events be expected, and what will be the impact to the Bay?

4. **What is the effect of increased atmospheric CO_2 levels on water chemistry and organism populations in the Bay?**
   It has been determined in studies of sea water that as CO_2 levels rise, there is a decrease in water pH and carbonate ion concentrations, with implications for marine organisms with pH and/or carbonate ion sensitivities. However, there do not appear to be studies on estuarine systems where water chemistry can already vary greatly from sea water. Similarly, it has been difficult to predict the result of increased CO_2 levels on populations of photosynthetic organisms.

5. **What is the expected frequency and volume of future precipitation in the watershed?**
   Questions remain regarding the timing of precipitation events in the watershed and the seasonal volume of precipitation. More accurate information is needed in this regard, as streamflow is a critical factor influencing the Bay's water circulation and biogeochemistry, including dissolved oxygen levels.

6. **How will changes to terrestrial ecosystems impact loadings to the Bay?**
   One example of a terrestrial ecosystem important to water quality is forest. It has been shown that different tree species and their resulting litter affect nitrogen cycling differently. Changes in species distribution resulting from climate change could therefore impact nitrogen loadings. With forests comprising 60 percent of the

Bay watershed, these changes have the potential to be significant, but predictions regarding these changes must become more certain.

7. **What is the probable impact of climate change on Bay circulation?** Will temperature and salinity changes interact to change historic patterns of stratification in the Bay?

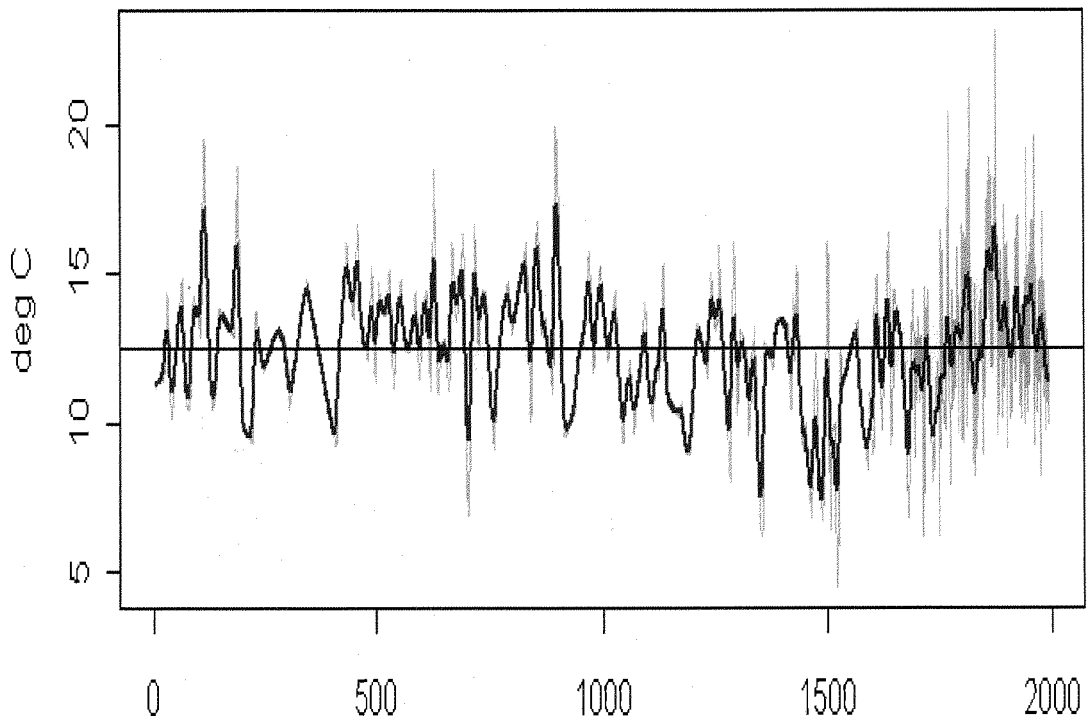
8. **Will changes in temperature alter the behavior and distribution of fish, shellfish, their habitat, the organisms on which they feed, and pathogens?**

Inherent in each of these data gaps is a question regarding the proper role of public policy in addressing the results. For instance, if CSOs do not adequately accommodate increased volumes of stormwater resulting from climate change, what additional stormwater management should be implemented, by what means, and by which entity? How should local land use decisions take into consideration future changes in sea level and storm surge? How should fisheries management plans take into account altered migration patterns or food sources?

Conclusion

Of primary importance is the facilitation of a coordinated, Bay-focused effort to determine the impacts of climate change. Many feel that sea level rise may be the most costly and threatening of the potential climate change impacts to coastal communities and natural resources in the Bay. The potential of this risk and the attendant costs of losing both ecosystem service values and billions in public infrastructure are significant. As a result, there is a vital need for an assessment of the adequacy of our financial and regulatory systems, currently available, to restore or replace the built and natural infrastructure. This is especially important in a multi-jurisdictional setting where several climate policies with significant implications are already in various stages of formation and implementation. Fortunately, the Chesapeake region has a 30-year history of public, private, and academic partnerships and ecosystem management. By applying this cooperative model to the issue of climate change, and integrating climate change factors into Bay restoration decision-making, the region can be in a position of leadership for the rest of the country and the world.

Spring SST Estimates at Chesapeake Bay for 2000 Years



Cronin et al. (2003) Global and Planetary Change, vol. 36, 17-29

plot made available by Steve McIntyre

SUPPLEMENT TO
Testimony Before the
United States Senate
Committee on Environment and Public Works
Washington, D.C.

Submitted to the Record
October 3, 2007

A Framework to Prevent the Catastrophic Effects of Global Warming using Solar Radiation Management (Geo-Engineering)

Presented by
David W. Schnare, Esq. Ph.D.[1]
Thomas Jefferson Institute for Public Policy

Purpose of Supplemental Testimony

At the September 26, 2007, hearing of the Senate Environment and Public Works Committee, Senator Mikulski (Chairman, Appropriations Subcommittee on Commerce, Justice, Science and Related Agencies) and participating in the hearing by accord of the Committee, specifically requested me to supplement my testimony for the record by providing a specific "Framework" by which to address Climate Change using geo-engineering.

The Framework below relies on the National Academy of Sciences 1992 recommendations on geo-engineering for climate change mitigation. It also reflects the extensive, recent contributions of researchers working at the U.S. Environmental Protection Agency, the Lawrence Livermore National Laboratory and the Department of Global Ecology, Carnegie Institution at Stanford University.

The 1992 NAS Recommendation

In 1992, the National Academy of Sciences, Committee on Science, Engineering, and Public Policy, released a major report entitled "Policy Implications of Greenhouse Warming." In that report, the NAS raised and evaluated three questions regarding use of geo-engineering, and specifically Solar Radiation Management (SRM) to prevent the catastrophic effects of ice sheet melting due to global warming:

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[1] Dr. Schnare is the Institute's Senior Fellow for Energy and the Environment. His position with the Institute is *pro bono*. He has been employed by the U.S. Environmental Protection Agency for 30 years and currently serves as a Senior Counsel in the Office of Civil Enforcement prosecuting violations of the nation's Clean Air Act. This testimony reflects the views of the author and does not necessarily reflect the position of the U.S. EPA or the Thomas Jefferson Institute.

> 1. Does it appear feasible that engineered systems could actually mitigate the effects of greenhouse gases?
>
> 2. Does it appear that the proposed systems might be carried out by feasible technical means at reasonable costs?
>
> 3. Do the proposed systems have effects, besides the sought-after effects, that might be adverse, and can these be accepted or dealt with?

The Academy concluded the answer to the first two questions was "yes" and that it was time to more fully evaluate the third:

> An exhaustive literature search and analysis has not been completed, but it has been possible to find useful material in the literature and to make first-order estimates that suggest positive answers to these first two questions. This being the case, it seems appropriate to continue consideration of the range of geoengineering possibilities and to pursue answers to question 3 above.

The Promise and Risks of Solar Radiation Management

In the past 15 years, Solar Radiation Management (SRM) has been examined by two premier scientific groups. Lowell Wood has investigated the practicalities and risks of this approach in considerable depth. He is currently on the staff at the Lawrence Livermore National Laboratory. Ken Calderia, of the Department of Global Ecology, Carnegie Institution, has done confirmatory work at Carnegie and Livermore.

Caldeira concluded that shading the sunlight directly over the polar ice cap by less than twenty-five percent would maintain the "natural" level of ice in the Arctic, even with a doubling of atmospheric CO2 levels. By increasing the shading to fifty percent, and the ice shelves grow. Further, the restoration happens fast. Within five years, the temperature would drop by almost two degrees, stabilizing the ice, saving the polar bears and the Inuit population, and demonstrating the efficacy of planetary engineering for $1/36^{th}$ the amount appropriated to assist in recovery of the hurricane flooding disaster in New Orleans. If the aerosols are launched only over the Arctic, there is little danger of directly impacting many humans. As well, the approach is incremental and can be expanded or shut down at will so that temperature effects dissipate within months, returning the region to its "natural" state.

All researchers examining this form of geo-engineering also recognize that, at best, it is no more than a way to buy time to develop clean energy technologies. It is not a solution to the greenhouse gas problem, only a means to prevent the worst of the environmental impacts of greenhouse gases while finding ways to shift away from carbon-based fuels.

The Immediate Need for Solar Radiation Management (SRM) Research

Regarding the need for solar radiation management (using sulfate particles), Paul J. Crutzen, Nobel Laureate for his work on the ozone hole and considered one of the world's premier atmospheric physicist, stated last year:

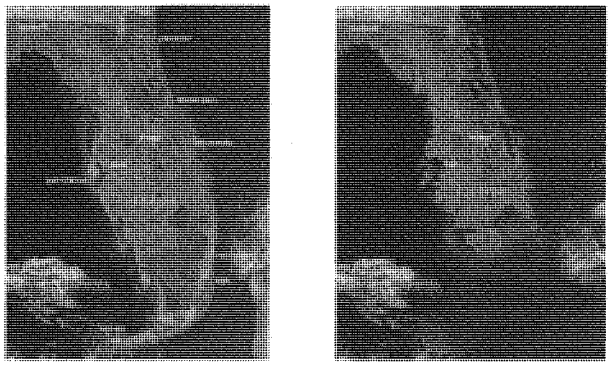
> "the very best would be if emissions of the greenhouse gases could be reduced so much that the stratospheric sulfur release experiment would not need to take place. Currently, this looks like a pious wish."

James Hansen, recognized as this nation's leading governmental climate scientist, has predicted that massive ice sheet melting may cause damaging increases in sea levels within the next few decades, unless global temperatures can be reduced.

> "Present knowledge does not permit accurate specification of the dangerous level of human-made GHGs. However, it is much lower than has commonly been assumed. If we have not already passed the dangerous level, the energy infrastructure in place ensures that we will pass it within decades [not centuries]."

The pictures below show the effect of the predicted sea level rise on the State of Florida. We would lose three major metropolitan cities, Miami, Fort Lauderdale and Saint Petersburg, as well as the nation's trillion dollar investment at Cape Canaveral potentially by as soon as 2050.

Figure 1



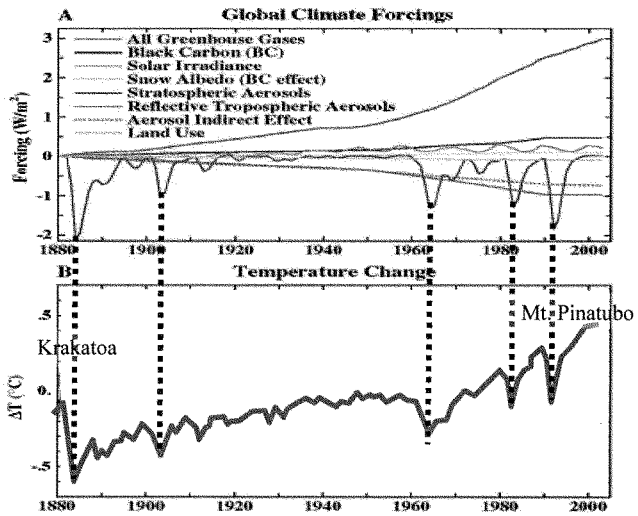
How Solar Radiation Management Works

It has long been recognized that particles in the atmosphere reflect incoming sunlight and thereby decrease the amount of heat retained by the Earth. In essence, they lower the global temperature. Although quickly removed by rain in the troposphere, they have a much longer life in the upper

atmospheric levels, the stratosphere. In the language of physics, these particles "force" temperatures to go down. Greenhouse gases, in contrast, force temperatures to go up.

Volcanic eruptions show the effect of stratospheric particles on temperature. The figures below show the size of various "forcings," including stratospheric particles, over the last 125 years. Note the exact correlation between the volcanic eruptions (upper blue line) and reduced global temperatures. Note the size and speed of temperature reductions from these stratospheric aerosols. They are sufficient to counter-balance the effects of greenhouse gases.

Figure 2



For this reason both the National Academy of Sciences (1992) and Nobel Prize winner Paul Crutzen (2006) have recognized the usefulness of this effect to prevent/control climate change.

The purpose of the Framework below is to outline how solar radiation management, using stratospheric particles, can be evaluated and employed with complete certainty and within the time needed to prevent the most catastrophic effects of global warming.

The Framework below is based on solar radiation management (SRM) as detailed by Alan Carlin (2007a and 2007c), and as conceived by Wood, Caldeira and others.

Relationship of Geo-Engineering to Greenhouse Gas Reduction

It is important to note that the use of solar radiation management does not conflict in any way with proposals to reduce GHG emissions to control global warming. When and if these proposals should bring about actual reductions in GHG emissions, the scope of SRM efforts could simply be scaled back so as to continue to achieve the objectives defined in the Framework offered below. That is, the two approaches are complimentary and not "either-or." If successfully implemented, both approaches can theoretically control climate change. As explained above, however, it is very doubtful that GHG emissions control could prevent dangerous climate changes. (Carlin, 2007c).

A Framework for Implementing Solar Radiation Management to Prevent the Catastrophic Consequences of Global Warming

The Framework would consist of five core elements, each of which is essential to application of the proposed geo-engineering. These five elements reflect the concerns of the National Academy of Sciences and the consensus of climate scientists and economists conducting both science and policy research on geo-engineering.

1. **Precisely Define Solar Radiation Management Objectives:**

In light of the potential to apply SRM incrementally, much like adjustment of a global thermostat, and in light of the potential for any nation or consortium to use SRM without "permission," the first element of the Framework is specification of the objective being sought so that any nation or international body would have a basis for responsible action. Objective (3), below, discusses the need for an international body to address actual implementation of SRM.

Proposed Objective:

> **Maintain the global energy balance at a level that will preserve the historic mass of all three major ice sheets (Greenland, West Antarctic, and East Antarctic).**

This objective might be modified to require additional cooling in the short term to offset the heating now underway and causing accelerated melting of the Arctic ice, should it be decided that the world does not wish to have a North-West Passage available for shipping and other purposes. Presumably the cooling offered by SRM would be roughly equivalent to that created by the Mount Pinatubo eruption in 1992 (the last blue blip down in stratospheric aerosol forcing shown in Figure 2, above). The proposed objective reflects prevention of the primary catastrophic effect of global warming, sea level rise, an event that would displace more than a quarter of the population of the world and, as former Vice-President Gore suggests, would end civilization as we know it.

2. SRM Research:

Although there is no question that a nation could successfully implement SRM by doing no more than replicating the major volcanic eruptions, Dr. Wood recommends more optimum types of particles and more targeted placement of them into the stratosphere. We need research on each of the following:

a. The optimal size, composition, and placement of particles (elevation and geographic coverage) and determination of the optimum radiation wavelengths to be reduced, in order to achieve the Framework Objective;

b. The particle quantities required as a function of temperature reduction (energy balancing) as needed to meet the Framework Objective, *i.e.*, in order to preserve the historic mass of all three major ice sheets;

c. Evaluation of the optimal transport mechanism to carry particles into stratosphere;

d. Identification of, and evaluation of means to eliminate or reduce, potential adverse non-temperature environmental effects of particles;

For further discussion, see, references listed in footnote 119 of Carlin, 2007a.

3. Design and implement an institutional setting for use of SRM

Professor Barrett, Director of Johns Hopkins University's School of Advanced International Studies, argues there is an immediate need to examine how to manage SRM use through an international body, a policy recommendation also made by Alan Carlin of the U.S. Environmental Protection Agency (Barrett 2007, Carlin 2007). To prevent the political pathologies observed in the operations of the IPCC and the UN Environmental Program, an international institution patterned after the Federal Reserve Board or the International Monetary Fund might be expected to provide neutral leadership. Such an apolitical body would likely operate in small incremental steps, much as the Federal Reserve and the IMF do with monetary policy. Recalling that SRM could be implemented by a single country with the needed financial and technological resources, this element of the Framework would serve to ensure international consensus on this global activity.

4. Legislative Leadership to Limit SRM Legal Liability

Adjusting climates will create global winners but always has the potential to create some local losers. For example, a decision to cool the Arctic in order to prevent melting of the Greenland Ice Sheet would also likely close the North-West Passage and may limit rainfall above the Arctic Circle. Those relying on use of that passage or the rainfall would be losers. Although SRM is now expected to have few unintended consequences, risk of legal liability could prevent use of this geo-engineering. Congress will need to address this issue in order to ensure sensible and timely use of SRM. For a more extensive discussion of this issue, see Carlin, 2007a, p. 181.

5. Proposed Timeline

This Framework contemplates a five phase approach that would likely achieve its objective of guaranteeing prevention of catastrophic sea level rise within five years.

Phase I – Laboratory Research and Institutional Development: A consortium to include the national leaders in SRM, would conduct preliminary research and technical development work and draft a detailed plan to accomplish the necessary pilot scale testing of SRM, to include funding requirements. The ideal leader of this consortium would be Professor Wood (with significant assistance by Professor Caldeira and his colleagues), and would include institutional experts such as Professor Barrett at Johns Hopkins. Most physical research would involve laboratory scale physics and chemistry, as well as computer simulations, modeling, and analyses of the kind routinely conducted by climate scientists today. Simultaneously, the institutional research branch would identify alternative means to regulate and manage SRM use, to include formation of a specific objective such as presented in the first Element above. The plan would include a detailed proposal for formation of a control institution to test and regulate the use of SRM. The plan would ideally be reviewed and accepted by experts from a very wide spectrum of relevant disciplines (18 months, $3.5 million estimated).

Phase II: Careful real world testing of subscale versions of SRM at gradually increasing scales to verify any remaining questions and development of revised implementation plan; appointment and organization of the SRM control organization (18 months).

Phase III: Review research results and propose and take comment on an SRM schedule of events. This would be the first major action of the international SRM control body. It would include a reexamination of the objective to ensure adequate global support (18 months).

Phase IV: Solar Radiation Management (SRM) begins under international control through the SRM control body. Implementation would be transparent and would include continuing monitoring and reporting of physical effects as well as and semi-annual plan revisions based on new information gained. Full SRM for the geographic area selected/world would be realized within weeks of full implementation. Note that if the quantities are correctly selected, it would be possible to design SRM so that no further warming of the area selected/world would occur after that time regardless of other climatic events as long as an appropriate level of particles is maintained.

Phase V: Maintenance of SRM system based on continued comparisons between objectives (element 1 above) and actual achievements. The SRM program, if effective, would be expected to continue until no longer needed (when greenhouse gases are adequately controlled), and could be expected to remain in place for a century.

For a more lengthy discussion on some of the concepts underlying this Framework, see Carlin, 2007.

References

Barrett, Scott, 2007, "*The Incredible Economics of Geoengineering,*" Johns Hopkins University, School of Advanced International Studies (in press, Environmental and Resource Economics).

Carlin, Alan, 2007, "*Implementation and Utilization of Geoengineering for Global Climate Change Control,*" Sustainable Development Law and Policy, 7(2): 56-8 (Winter), available at http://www.wcl.american.edu/org/sustainabledevelopment/2007/07winter.pdf?rd=1

Carlin, Alan, 2007a, "*Global Climate Change Control, Is There a Better Strategy than Reducing Greenhouse Gas Emissions?*" University of Pennsylvania Law Review, 155(6): 1401-1497 (June), available at http://pennumbra.com/issues/articles/155-6/Carlin.pdf

Carlin, Alan, 2007b, "*New Research Suggests that Emissions Reductions May Be a Risky and Very Expensive Way to Avoid Global Climate Changes,*" Working Paper No. 2007-07, National Center for Environmental Economics, USEPA, available at http://yosemite.epa.gov/EE/epa/eed.nsf/WPNumberNew/2007-07.

Carlin, Alan, 2007c, "*Risky Gamble,*" Environmental Forum, 24(5): 42-47 (September/October), available at http://carlineconomics.googlepages.com/CarlinEnvForum.pdf

Crutzen, P.J., 2006, "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?" *Climatic Change*, 7: 211, available at http://downloads.heartland.org/19632.pdf.

Hansen, James, et al., 2005, "*Earth's Energy Imbalance: Confirmation and Implications,*" *Science*, 308(5727): 1431-1435 (June 3).

Hansen, James et al, 2007 "*Climate change and trace gases*" Phil. Trans. R. Soc. A 365, pp. 1925–1954

National Academy of Sciences, 1992, Committee on Science, Engineering, and Public Policy, "Policy Implications of Greenhouse Warming", pp. 433-460, available at http://www.nap.edu/catalog.php?record_id=1605.

Schnare, David, 2007, *"Responses to Climate Change and their Implications on Preservation and Restoration of the Chesapeake Bay"*, Testimony Before the United States Senate Committee on Environment and Public Works, Washington, D.C., Wednesday, September 26, 2007, available at http://thehardlook.typepad.com/thehardlook/files/schnare_senate_epw_testimony_9262007.pdf.

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