POLICY RELEVANT CLIMATE ISSUES IN CONTEXT

HEARING

BEFORE THE

SUBCOMMITTEE ON ENVIRONMENT

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED THIRTEENTH CONGRESS

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THURSDAY, APRIL 25, 2013

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Thursday, April 25, 2013

POLICY RELEVANT CLIMATE ISSUES IN CONTEXT

THURSDAY, APRIL 25, 2013

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENVIRONMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:03 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Chris Stewart [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

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Subcommittee on Environment

Policy Relevant Climate Issues in Context

Thursday, April 25, 2013
10:00 a.m. -11:30 a.m.
2318 Rayburn House Office Building

Witnesses

Dr. Judith Curry, Professor, School of Earth and Atmospheric Sciences, Georgia Institute of Technology

Dr. William Chameides, Dean and Professor, Nicholas School of the Environment, Duke University

Dr. Bjørn Lomborg, President, Copenhagen Consensus Center

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTE ON ENVIRONMENT

HEARING CHARTER

Policy Relevant Climate Issues in Context

Thursday, April 25, 2013
10:00 a.m. – 11:30 a.m.
2318 Rayburn House Office Building

Purpose

On Thursday, April 25, 2013, the Subcommittee on Environment will hold a hearing entitled *Policy Relevant Climate Issues in Context.* The purpose of the hearing is to provide Members a high level overview of the most important scientific, technical, and economic factors that should guide climate-related decision-making this Congress. Specifically, this hearing will examine the current understanding of key areas of climate science necessary to inform decision-making on potential mitigation options.

Witnesses

- **Dr. Judith Curry**, Professor, School of Earth and Atmospheric Sciences, Georgia Institute of Technology
- **Dr. William Chameides**, Dean and Professor, Nicholas School of the Environment, Duke University
- **Dr. Bjørn Lomborg,** President, Copenhagen Consensus Center

Background

Climate science—and climate-related regulatory actions informed by such science—are among the most complex and controversial issues facing policymakers. After several years of relatively quiet legislative and regulatory activity within Congress and the Executive Branch, climate policy is again receiving renewed attention.

Since winning re-election in November, 2012, President Obama has increasingly signaled his intention to propose significant, new executive actions and regulatory measures aimed at addressing climate concerns. At his inaugural address in January, the President stated:

> We will respond to the threat of climate change, knowing that the failure to do so would betray our children and future generations. Some may still deny the overwhelming judgment of science, but none can avoid the devastating impact of raging fires and crippling drought and more powerful storms.

The President elaborated on this at last month's State of the Union address, and indicated he would direct his Cabinet to propose specific actions for his consideration. Specifically, he stated:

> But for the sake of our children and our future, we must do more to combat climate change. Yes, it's true that no single event makes a trend. But the fact is, the 12 hottest years on record have all come in the last 15. Heat waves, droughts, wildfires, and floods – all are now more frequent and intense. We can choose to believe that Superstorm Sandy, and the most severe drought in decades, and the worst wildfires some states have ever seen were all just a freak coincidence. Or we can choose to believe in the overwhelming judgment of science – and act before it's too late.
>
> The good news is we can make meaningful progress on this issue while driving strong economic growth. I urge this Congress to pursue a bipartisan, market-based solution to climate change, like the one John McCain and Joe Lieberman worked on together a few years ago. But if Congress won't act soon to protect future generations, I will. I will direct my Cabinet to come up with executive actions we can take, now and in the future, to reduce pollution, prepare our communities for the consequences of climate change, and speed the transition to more sustainable sources of energy.

While it is unclear what specific form the President's proposals will take, it has been widely reported that new Environmental Protection Agency (EPA) regulations restricting greenhouse gas emissions from existing power plant facilities will serve as a centerpiece of the President's climate efforts. In March 2012, EPA proposed greenhouse gas regulations for new power plants.[1] While this rule has yet to be finalized, the Agency's Regulatory Impact Analysis that accompanied this proposal emphasized some of the key challenges associated with incorporating uncertain scientific, technological, and economic information into such regulatory decisions:

> When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment, and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.[2]

This characterization is indicative of the likely challenges associated with future climate-driven regulatory proposals as well. Therefore, it is likely that Congressional review and response of such proposals will be heavily informed by the understanding of a combination of science, technological feasibility, and value judgments such as economic tradeoffs and opportunity costs.

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[1] http://yosemite.epa.gov/opa/admpress.nsf/79c090e81f0578738525781f0043619b/9b4e8033d7e641d9852579ce005ae957!OpenDocument

[2] http://www.epa.gov/ttnecas1/regdata/RIAs/egughgnspsproposalria0326.pdf

The purpose of this hearing is to examine key factors that will guide these decisions, particularly as they relate to the understanding of climate change-related risks facing the country, associated probabilities and uncertainties, and the costs and benefits of various mitigation proposals.

Resources

At the Federal agency level, climate-related regulatory and programmatic decision-making relies significantly on the following scientific entities:

- International Governmental Panel on Climate Change (IPCC)—international scientific body organized under the United Nations Environment Programme (UNEP). Notably, the IPCC is currently undertaking work on the Fifth Assessment Report (AR5), which is intended to be completed in 2013/2014 and provide an update of knowledge on the scientific, technical and socio-economic aspects of climate change.[3]

- U.S. Global Change Research Program (USGCRP)—coordinates and integrates Federal research on changes in the global environment and their implications for society. Mandated by Congress as part of the Global Change Research Act of 1990 (PL 101-606), USGCRP oversees 13 agencies supporting approximately $2.6 billion annually in climate change research.[4]

- National Climate Assessment and Development Advisory Committee (NCADAC)—created in December 2010, the NACDAC is a non-governmental advisory committee organized under and reporting to USGCRP. NACDAC is charged with producing a National Climate Assessment that "integrates, evaluates, and interprets the findings of the U.S. Global Change Research Program (USGCRP) and discusses the scientific uncertainties with such findings." In January, NACDAC released a major *Draft Climate Assessment Report* for review and comment. The Comment period closes on April 12, 2013.[5]

Additional Information

Witnesses were asked to address the following questions in their testimony:

Dr. Judith Curry

- Summarize your views on the most important policy-relevant climate science issues facing decision-makers. What are the key areas of agreement and disagreement? What is the state of the science and associated strengths and weaknesses on key policy relevant issues, such as attribution, modeling and observations, and climate sensitivity?
- Describe the state of the science on the linkages between climate change and extreme weather. Include a discussion on the key uncertainties of these connections and describe how such uncertainties are treated in the public discussion of extreme weather events. What is needed to reduce misconceptions surrounding this scientific discipline?

[3] http://www.ipcc.ch
[4] www.globalchange.gov
[5] http://ncadac.globalchange.gov/

- Include a broad discussion of uncertainties within climate change science, specifically addressing challenges and opportunities related to decision-making under uncertainty, including how such uncertainties are conveyed to policymakers and the public.

Dr. William Chameides

- Discuss the state of climate science and summarize your views on the most important climate science issues facing decision-makers.
- Describe future projected impacts of most concern in the United States with regard to climate change, and actions the federal government can take to address future impacts.
- Provide a discussion of scientific uncertainties in climate science and the how decision makers can account for uncertainty in crafting climate-related policies.

Dr. Bjorn Lomborg

- Summarize your views on the most important policy-relevant climate issues facing decision-makers. What are the key areas of agreement and disagreement?
- Describe the strengths and weakness of various climate change-driven policies currently in effect around the world, and the costs and benefits of potential mitigation options under consideration here in the United States. How could limited Federal resources be better allocated to address climate, environmental and human health issues facing the U.S. and other nations around the world?

Chairman STEWART. The Subcommittee on the Environment will come to order. Good morning, everyone. Welcome to today's hearing, entitled "Policy Relevant Climate Issues in Context." In front of you are packets containing the written testimonies, biographies, and truth in testimony disclosures for today's witness panels.

I now recognize myself for five minutes for an opening statement.

First, I would like to welcome the witnesses today. I thank you for your service, and for your sacrifice in being here with us. We look forward to an interesting exchange with you. I will have a chance to introduce the witnesses later on. I would also like to welcome the full Committee Chairman, Chairman Smith.

At his State of the Union address last month President Obama cited as evidence of climate change that heat waves, droughts, wildfires, and floods are all now more frequent and intense. After calling this issue one of the greatest priorities of his second term, he then signaled his intention to move forward with aggressive actions in climate change. While the details of the President's plans are not yet known, today's hearing is intended to provide Members a high level overview of the key factors that should inform our decision-making on what is, unfortunately, one of the most controversial public policy issues of our day.

Nobel Prize winning physicist Niels Bhor, later followed by the noted philosopher Yogi Berra, famously said, "Prediction is very difficult, especially if it is about the future." The scientific and political rhetoric associated with climate change would benefit greatly from the humility espoused by these two gentlemen. For example, the number and complexity of factors influencing climate, from land and oceans, to sun and clouds, make precise long term temperature predictions an extremely difficult challenge. This may help explain why consensus climate models, likely to serve as a basis for major economy-wide regulatory actions, have such poor track records. These models regularly overstate the actual temperature changes and have failed to predict the current 16 year absence of global warming. And I would like to emphasize that point, if I could. Contrary to the predictions of almost all modeling, over the past 16 years there has been a complete absence of climate—global warming.

There are two obvious lessons here. First, modeling predictions are not infallible. And second, while we encounter those who claim to know precisely what our future climate will look like, and then attack anyone who may disagree with them, when that happens, we have stepped out of the arena of science and into the arena of politics and ideology. And it is important to recognize that the direction we choose to take on climate change is not resolved by science alone. Once the scientific analysis is complete, we must then make value judgments and economic decisions based on a real understanding of the costs and benefits of any proposed actions. It is through this lens that we should review the President's forthcoming executive actions and proposed regulations.

While we still don't know the specifics of the President's plans, we know enough to cause people such as myself great concern. I am worried that his anticipated restrictions in industrial CO_2 emissions may have no discernible impact on the climate, but will amount to a significant energy tax on the American people. And it

is important to note this isn't a cost that you can pass on to the millionaires and the billionaires that the administration likes to talk about. Much of these additional costs will be borne by those who can least afford it, retirees on fixed income, young families, and those on the bottom of the rung of the economic ladder. The President's proposals will also reduce our economic activity at a time when we can least afford it, while sending jobs overseas to countries like China and India.

If you care about the poor and the disadvantaged among us, then you must be very careful as you consider some of the President's proposals to combat climate change. The bottom line is this, not only should we consider the science behind climate change, but also the economic costs of implementing any suggested remedies. I look forward to discussing this in further detail with our witnesses today, and learning more about the best approach to this important issue of energy, climate, and the environment.

I yield back the balance of my time, and recognize the Ranking Member, Ms. Bonamici, for her opening statement.

[The prepared statement of Mr. Stewart follows:]

PREPARED STATEMENT OF SUBCOMMITTEE CHAIRMAN CHRIS STEWART

Good morning and welcome to this morning's Environment Subcommittee hearing entitled "Policy Relevant Climate Issues in Context."

At his State of the Union address earlier this year, President Obama cited as evidence of climate change that "heat waves, droughts, wildfires, and floods—all are now more frequent and intense." After calling this issue one of the greatest priorities of his second term, he then signaled his intention to move forward with aggressive actions to combat climate change. Today's hearing is intended to provide Members a high-level overview of the key factors that should inform our decision-making on what is unfortunately one of the most controversial public policy issues of our day.

Nobel Prize-winning physicist Neils Bohr—later followed by noted philosopher Yogi Berra—famously said, "Prediction is very difficult, especially if it's about the future." The scientific and political rhetoric associated with climate change could benefit greatly from the humility espoused by these two gentlemen.

For example, the number and complexity of factors influencing climate-from land and oceans to the sun and clouds-make precise long-term temperature predictions an extremely difficult challenge. This may help explain why "consensus" climate models likely to serve as the basis for major, economy-wide regulatory actions have such poor track records. These models regularly overestimate actual temperature changes and have failed to predict the current 16-year absence of global warming. And let me emphasize this last statement—contrary to the predictions of almost all modeling, over the past 16 years there has been a complete absence of global warming.

There are two obvious lessons here. First, modeling predictions are not infallible. Second, when we encounter those who claim to know precisely what our future climate will look like, and then attack any who may disagree with them, we have stepped out of the arena of science and into the arena of politics and ideology.

It is also important to recognize that the direction we choose to take on climate change is not resolvable by science alone. Once the scientific analysis is complete, we must then make value judgments and economic decisions based on a real understanding of the costs and benefits of any proposed actions.

It is through this lens that we should review the President's forthcoming executive actions and proposed regulations.

While we still don't know all the specifics of the President's plan, we know enough to cause me great concern. I am worried that his anticipated restrictions on industrial CO_2 emissions may have no discernible impact on climate, but will amount to a significant energy tax on the American people. I am also concerned that his proposals will reduce our economic activity at a time when we can least afford to do that, while sending jobs overseas to countries such as China and India. I look forward to discussing this in further detail with our witnesses today, and learning

more about how best to approach the important issues of energy, climate, and the environment.

I yield back the balance of my time, and recognize Ranking Member Bonamici for an opening statement.

Ms. BONAMICI. Thank you very much, Mr. Chairman, for holding this hearing. I would like to thank our witnesses for being here today. This is an important issue. In fact, I want to thank the chair of the full Committee as well. Ranking Member Eddie Bernice Johnson and I sent a letter before this earlier scheduled hearing emphasizing the importance of this topic.

The reality of climate change is increasingly impossible to deny. Over the past 25 years numerous scientists from the United States and around the world have appeared before Congress to testify about climate change. Countless peer review studies have shown that climate change is real, and that humans are a significant contributing factor. Now we must shift the debate to planning, and discuss what actions we should take to mitigate the environmental, economic, and health effects that will inevitably hit our communities.

The stated subject of this hearing is policy relevant climate issues. Because a preponderance of scientific evidence shows that human activity is contributing to changes in the global climate, I submit that all climate change issues have become policy relevant. The United States, a large historical producer, and second largest current producer of greenhouse gases, bears a great responsibility to the rest of the world to ensure that we promote policies that will reduce the amount of greenhouse gases we continue to place in the Earth's atmosphere. We have the talent and ability to take on this important leadership role. We should also, as a country, have the will to do so.

Glacial withdrawal, loss of sea ice, ocean acidification, rising temperatures in sea levels are real and measurable problems. Although the effects of climate change are global, the impacts of this change are already felt throughout the United States. Recent droughts in the American southwest and historic severe weather events throughout the country are recent examples. According to the National Oceanic and Atmospheric Administration and NASA, 2012 was the warmest year on record in the United States, and the nine warmest years have all occurred since 1998.

Climate change affects our economy. In my State of Oregon, we have developed a reputation for growing quality wine grapes, including world renowned Pinot Noir. Much of the quality is attributable to the climate in Oregon, where the Pinot grapes grow at a temperature range between 57 and 61 degrees. Even a minor variation in temperature can threaten the continued quality, and hence value, to the Oregon economy of wines in the region.

Another important impact of global climate change on the economy in the Pacific Northwest, and other coastal areas, includes the effect of ocean acidification on the shellfish industry. The district I represent is home to a thriving fishing community, and in recent years oceanic and atmospheric changes have caused low oxygen content in the water, hypoxia, that has created dead zones that kill fish, crab, and other marine life. Agriculture and fishing are just two examples of industries concerned about climate change, and they are looking to their policymakers for solutions.

Climate change also has broad implications on other aspects of our Nation's economy. The Federal Government assists those who are hard hit by harsh weather events, and scientists point to in-

creasingly severe weather patterns as further evidence of the changing climate. The Government Accountability Office recently released a report that, for the first time, lists climate change as a significant financial risk to the Federal Government. The report adds that the Federal Government is not well positioned to address the fiscal exposure presented by climate change.

As a Nation, we are becoming too familiar with the consequences of waiting until the 11th hour to develop solutions to the problems we face. Let us not make the mistake with something as serious as climate change. And even though we may have differences of opinion about what is causing climate change, we can still discuss the economic gains we can make by investing in a clean energy economy, modernizing our infrastructure, and seeking energy independence. The United States has been a leader in renewable energy technology and climate research. We must continue our leadership if we intend to leave our children and grandchildren a clean and healthy environment in which they can thrive economically.

Thank you, Mr. Chairman. I look forward to the testimony from these experts today, and I yield back the balance of my time.

[The prepared statement of Ms. Bonamici follows:]

PREPARED STATEMENT OF SUBCOMMITTEE RANKING MEMBER SUZANNE BONAMICI

Mr. Chairman, thank you for holding this hearing, and I would like to thank our witnesses for being here today.

The reality of climate change is increasingly impossible to deny. Over the past 25 years, numerous scientists from the United States and around the world have appeared before Congress to testify about climate change. Countless peer-reviewed studies have shown that climate change is real and that humans are a significant contributing factor. Now we must shift the debate to planning and discuss what actions we should take to mitigate the environmental, economic, and health effects that will inevitably hit our communities.

The stated subject of this hearing is "policy-relevant" climate issues. Because a preponderance of scientific evidence shows that human activity is leading to changes in the global climate, I submit that all climate issues have become "policy-relevant." The United States, a large historical producer and second largest current producer of greenhouse gases, bears a great responsibility to the rest of the world to ensure that we promote policies that will reduce the amount of greenhouse gases we continue to place in the Earth's atmosphere. We have the talent and ability to take on this important leadership role; we should also, as a country, have the will to do so.

Glacial withdrawal, loss of sea ice, ocean acidification, and rising temperatures and sea levels are real and measurable problems. Although the effects of climate change are global, the impacts of this change are already felt throughout the U.S. Record droughts in the American Southwest and historic severe weather events throughout the country are recent examples. According to the National Oceanic and Atmospheric Administration (NOAA) and NASA, 2012 was the warmest year on record for the United States, and the nine warmest years have all occurred since 1998.

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Another important economic impact of global climate change in the Pacific Northwest and in many coastal areas is the effect of ocean acidification on the shellfish industry. My district is home to a thriving fishing community. In recent years, oceanic and atmospheric changes have caused low-oxygen content in the water—a condition known as hypoxia—that has created dead zones that kill fish, crab, and other marine life.

Agriculture and fishing are just two examples of industries concerned about climate change—they are looking to their policymakers for solutions.

Climate change also has broad implications on other aspects of our nation's economy. The federal government assists those who are hit hard by harsh weather events, and scientists point to increasingly severe weather patterns as further evidence of the changing climate. The Government Accountability Office recently released a report that, for the first time, lists climate change as a "significant financial risk to the federal government." The report adds "the federal government is not well-positioned to address the fiscal exposure presented by climate change."

As a nation, we are becoming too familiar with the consequences of waiting until the eleventh hour to develop solutions to the problems we face. Let's not make that mistake with something as serious as climate change. And even though we may have differences of opinion about what is causing climate change, but we can still discuss the economic gains we can make by investing in a clean energy economy, modernizing our infrastructure, and seeking energy independence. The United States has been a leader in renewable energy technology and climate research. We must continue our leadership if we intend to leave our children and grandchildren a clean and healthy environment in which they can thrive economically.

Thank you, and I yield back the balance of my time.

Chairman STEWART. Thank you, Ms. Bonamici.

I now recognize the chair of the full Committee, Mr. Smith, for his opening statement.

Chairman SMITH. Thank you, Mr. Chairman.

Mr. Chairman, climate change is an issue that needs to be discussed thoughtfully and objectively. Unfortunately, it is sometimes surrounded by claims that conceal the facts and hinder the proper weighing of policy decisions. I believe in the integrity of science, and challenging accepted beliefs through open debate and critical thinking is a primary part of the scientific process. To make rational decisions about climate change, we need to examine the relevant scientific issues, along with the costs and benefits, and better understand the uncertainties that surround both.

As we will hear today, there is still a great amount of uncertainty associated with our understanding of human influences on climate. A recent article in "The Economist" pointed out that climate models have greatly over-predicted warming. In fact, global temperatures have held steady over the last 15 years, despite rising greenhouse gas emissions. "The Economist" calls the lack of warming a surprise. It notes that the climate might be changing in ways not properly understood, which could have profound significance for climate science, and for environmental and social policy. This statement, from a respected publication that had previously supported aggressive emission controls, highlights the complexity of the climate issue. It calls attention to the limits of our understanding as to its causes. There is still much we don't know.

I am concerned that the administration now seeks to lock in an inflexible regulatory framework based on a limited understanding of the challenge. I am also concerned that these regulations may hinder economic development and our ability to deal with this and other challenges that lie before us. Several Federal Government agencies have implemented policies that drive up energy prices, burden employers, and cost us jobs, but many of these rules have no meaningful impact on climate change.

For example, the Environmental Protection Agency proposed standards that virtually prohibit new coal fired power plants from being built, and regulations that affect existing power plants and refineries may soon follow. Analysis of EPA's regulatory options reveal that these regulations will significantly increase the price of electricity and gasoline. At the same time, the agency has stated that cutting U.S. emissions will have little or no effect on global greenhouse gas concentrations due to growing emissions in a developing world, particularly China and India.

A recent Energy Information Administration report shows that U.S. reductions in emissions have little effect globally. It found that U.S. domestic carbon dioxide emissions decreased by 12 percent between 2005 and 2012, more than any other nation. Global emissions actually increase by 15 percent over roughly the same period. Affordable, reliable energy is key to a healthy economy. American consumers and small and large businesses all depend on reliable and affordable energy. It is only through sustained economic growth that we will be able to make the investments in research and technology necessary to fully understand and properly deal with problems like climate change. We should take a step back

from the claims of impending catastrophe and think critically about what we know, and what we don't know, about this issue. While it may require us to question some accepted views, that may be what is necessary for us to fully understand the signs of climate change and determine a rational policy response.

Mr. Chairman, I just want to make the observation that I think this is an exceptionally knowledgeable panel of experts and witnesses we have before us today, and I very much look forward to their testimony. Now I yield back.

[The prepared statement of Mr. Smith follows:]

PREPARED STATEMENT OF COMMITTEE CHAIRMAN LAMAR S. SMITH

Climate change is an issue that needs to be discussed thoughtfully and objectively. Unfortunately, it's sometimes surrounded by claims that conceal the facts and hinder the proper weighing of policy options.

I believe in the integrity of science. And I find it unfortunate that those who question certain scientific views on climate have their motives impugned. Challenging accepted beliefs through open debate and critical thinking is a primary part of the scientific process. To make a rational decision on climate change, we need to examine the relevant scientific issues along with the costs and benefits and better understand the uncertainties that surround both.

As we will hear today, there is still a great amount of uncertainty associated with our understanding of human influences on climate. A recent article in The Economist pointed out that climate models have greatly over-predicted warming. In fact, global temperatures have held steady over the past 15 years despite rising greenhouse gas emissions.

The magazine calls the lack of warming a "surprise." It notes that the climate might be changing in ways not properly understood, which "could have profound significance for climate science and for environmental and social policy."

This statement, from a respected publication that had previously supported aggressive emission limits, highlights the complexity of the climate issue. It calls attention to the limits of our understanding as to its causes. Indeed, there is much we don't know. I am concerned that the Administration now seeks to lock in an inflexible regulatory framework based on a limited understanding of the challenge. I'm also concerned that these regulations may hinder economic development and our ability to deal with this and other challenges that lie before us.

Several federal government agencies now implement policies that drive up energy prices, burden employers and cost us jobs. But, many of these rules have no meaningful impact on climate change. For example, the Environmental Protection Agency (EPA) has proposed standards that virtually prohibit new coal-fired power plants from being built. And regulations that affect existing power plants and refineries are soon to follow. Analyses of EPA's regulatory options reveal that these regulations will significantly increase the price of electricity and gasoline.

At the same time, the Agency has stated that cutting U.S. emissions will have little or no effect on global greenhouse gas concentrations due to growing emissions in the developing world, particularly China and India. A recent Energy Information Administration report shows that U.S. reductions in emissions have little effect globally. It found that U.S. domestic carbon dioxide emissions decreased by 12 percent between 2005 and 2012—more than any other nation. Global emissions actually increased by 15 percent over roughly the same period.

Affordable, reliable energy is key to a healthy economy. American consumers and small and large businesses all depend on reliable and affordable energy. It is only through sustained economic growth that we will be able to make the investments in research and technology necessary to fully understand and properly deal with problems like climate change. We should take a step back from the claims of impending catastrophe and think critically about what we know and what we don't know about this issue.

While it may require us to question some scientific views, that may be what is necessary for us to fully understand the science of climate change and determine a rational policy response.

Chairman STEWART. Thank you, Chairman Smith.

If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

At this time I would like to introduce our witnesses, and, as the full Committee Chairman recognized, this is an extraordinary panel.

Our first witness is Dr. Judith Curry, Professor and Chair of the School of Earth and Atmospheric Sciences at Georgia Institute of Technology, and President of the Climate Forecast Applications Network. Prior to joining Georgia Tech, she had faculty positions at the University of Colorado, Penn State University, and Perdue University. Dr. Curry also currently serves as the NASA Advisory Council, Earth Science Subcommittee, and the DOE Biological and Environment Research Advisory Committee. Dr. Curry received a Ph.D. in atmospheric science from the University of Chicago in 1982.

Our second witness today is Dr. William Chameides, Dean and Professor at the Nicholas School of the Environment, Duke University. Dr. Chameides has over 30 years of experience in academia as professor, researcher, and teacher. He is a member of the National Academy of Sciences. Previously Dr. Chameides worked at the Environmental Defense Fund as a chief scientist. He received his Ph.D. from Yale University.

Our final witness today is Dr. Bjorn Lomborg, Director of the Copenhagen Consensus Center, and adjunct professor at the Copenhagen business school. Dr. Lomborg is one of "Time" magazine's 100 most influential people, and one of the 75 most influential people of the 21st century, according to "Esquire" magazine. Dr. Lomborg received his Ph.D. in political science at the University of Copenhagen.

As our witnesses should know, and I am sure that you do, spoken testimony is limited to five minutes each, after which the Members of the Committee will have five minutes each to ask you questions.

I recognize now Dr. Curry for five minutes to present her testimony.

TESTIMONY OF DR. JUDITH CURRY, PROFESSOR, SCHOOL OF EARTH AND ATMOSPHERIC SCIENCES, GEORGIA INSTITUTE OF TECHNOLOGY

Dr. CURRY. I would like to thank the Subcommittee for the opportunity to offer testimony this morning. My name is Judith Curry. I am chair of the School of Earth and Atmospheric Sciences at Georgia Tech. For the past 30 years I have conducted research on topics that include climate feedback processes in the Arctic, the role of clouds and aerosols in the climate system, and the impact of climate change on hurricanes. As president of a small company, Climate Forecast Applications Network, I have worked with decision-makers on climate impact assessments and using short term climate forecasts to support adaptive management. I am also proprietor of the weblog Climate, Et Cetera.

For the past several years I have been promoting dialogue across a full spectrum of beliefs and opinion on the climate debate. I have

learned about the complex reasons that intelligent, educated, and well-informed people disagree on the subject of climate change, as well as tactics used by both sides to try to gain political advantage in the debate. Through my company, I have learned about the complexity of different decisions that depend on weather and climate information. I have learned the importance of careful determination and communication of forecast uncertainty, and the added challenges associated with predicting extreme weather events. I have found that the worst prediction outcome is a prediction issued with a high level of confidence that turns out to be wrong. A close second is missing the possibility of an extreme event.

If all other things remain equal, it is clear that adding more carbon dioxide to the atmosphere will warm the planet. However, the real difficulty is that nothing remains equal, and reliable prediction of the impact of carbon dioxide on the climate requires that we better understand natural climate variability. My written testimony summarized the evidence for and against the hypothesis that humans are playing a dominant role in global warming. I will make no attempts to summarize this evidence in my brief comments this morning. I will state that there are major uncertainties in many of the key observational data sets, particularly before 1980. There are also major uncertainties in climate models, particularly with regards to the treatment of clouds and the multi-decadal ocean oscillations.

The prospect of increased frequency or severity of extreme weather in a warmer climate is potentially the most serious near term impact of climate change. A recent report from the inter-governmental panel on climate change found limited observational evidence for worsening of most type of extreme weather events. Attempts to determine the role of global warming and extreme weather events is complicated by the rarity of these events, and also by their dependence on natural weather and climate regimes that are simulated poorly by climate models. Given these uncertainties, there would seem to be plenty of scope for disagreement among scientists. Nevertheless, the consensus about dangerous anthropogenic climate change is portrayed as nearly total among climate scientists. Further, the consensus has been endorsed by all of the relevant national and international science academies and societies.

I have been trying to understand how there can be such a strong consensus, given these uncertainties, excuse me. How to reason about uncertainties in the complex climate system is neither simple or obvious. Scientific debates involve controversies over the value and importance of particular classes of evidence, failure to account of indeterminacy and ignorance, as well as disagreement about the appropriate logical framework for assessing the evidence. For the past three years I have been working towards understanding the dynamics of uncertainty at the climate science policy interface. This research has led me to question whether these dynamics are operating in a manner that is healthy for either the science or the policy process.

The climate community has worked for more than 20 years to establish a scientific consensus on anthropogenic climate change. The IPCC's consensus-building process played a useful role in the early

synthesis of scientific knowledge on this topic. However, I have argued that the ongoing scientific consensus seeking process has had the unintended consequence of oversimplifying both the problem and its solutions, introducing biases into both the science and related decision-making processes.

When uncertainty is not well characterized, and there is concern about unknown unknowns, there is increasing danger of getting the wrong answer, and optimizing for the wrong thing. I have argued in favor of abandoning the scientific consensus seeking approach in favor of open debate and discussion of a broad range of policy options on the issues surrounding climate change. There are frameworks for decision-making under deep uncertainty that accept uncertainty and dissent as key elements of the decision-making process. Rather than choosing an optimal policy based on a scientific consensus, decision-makers can design robust and flexible policy strategies that are more transparent and democratic, and avoid the hubris of pretending to know what will happen in the future. The politicization of the climate change issue presents dawning challenges to climate science and scientists.

I would like to close with a reminder that uncertainty about the future climate is a two-edged sword. There are two situations to avoid. The first is acting on the basis of a highly competent statement about the future that turns out to be wrong, and the second is missing the possibility of an extreme catastrophic outcome. Avoiding both of these situations requires much deeper and better assessment of uncertainties and areas of ignorance, as well as creating a broader range of future scenarios than is currently provided by climate models.

This concludes my testimony.

[The prepared statement of Ms. Curry follows:]

STATEMENT TO THE
SUBCOMMITTEE ON ENVIRONMENT
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
OF THE UNITED STATES HOUSE OF REPRESENTATIVES

Hearing on
"Policy Relevant Climate Issues in Context"

25 April 2013

Judith A. Curry
Georgia Institute of Technology
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I thank the Chairman, the Ranking Member and members of the Subommittee for the opportunity to offer testimony today on *Policy Relevant Climate Issues in Context*. I am Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. I have devoted 30 years to conducting research on topics including climate feedback processes in the Arctic, energy exchange between the ocean and atmosphere, the role of clouds and aerosols in the climate system, and the impact of climate change on the characteristics of tropical cyclones. As President of Climate Forecast Applications Network (CFAN) LLC, I have worked with decision makers on climate impact assessments, assessing and developing meteorological hazard and climate adaptation strategies, and developing subseasonal climate forecasting strategies to support adaptive management.

Prior to 2005, I spent my time comfortably ensconced in the 'ivory tower' of academia, debating esoteric scientific issues with colleagues. Publication of a paper on hurricanes and global warming[1] several weeks after Hurricane Katrina exposed me to the rancor associated with the public debate surrounding climate change and the challenges and problems associated with mixing science and politics[2]. For the past several years, I have been promoting dialogue across the full spectrum of beliefs and opinion on the climate debate through my blog, Climate Etc. (judithcurry.com). I have learned about the complex reasons that intelligent, educated and well-informed people disagree on the subject of climate change, as well as tactics used by both sides to try to gain a political advantage in the debate. By engaging with decision makers in both the private and public sector on issues related to weather and seasonal climate variability through my company CFAN, my perspective on uncertainty and confidence in context of prediction, and how to convey this, has utterly and irreversibly changed. I have learned about the complexity of different decisions that depend, at least in part, on weather and climate information. I have learned the importance of careful determination and conveyance of the uncertainty associated with a forecast, and the added challenges associated with predicting extreme events. Confidence in a particular probabilistic forecast is determined by consistency of consecutive forecasts, and historical evaluation of forecast accuracy and errors under similar conditions. I have also learned how different types of decision makers make use of forecast uncertainty and confidence information. I have found that the worst forecast outcome is a forecast issued with a high level of confidence that turns out to be wrong; a close second is missing the possibility of an extreme event.

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[1] Webster, P.J., G.J. Holland, J.A. Curry, H.-R. Chang, 2005: Changes in tropical cyclone number, duration and intensity in a warming environment. *Science*. 309 (5742): 1844-1846. http://webster.eas.gatech.edu/Papers/Webster2005b.pdf

[2] Curry, J. A., P. J. Webster and G. J. Holland, 2006: Mixing Politics and Science in Testing the Hypothesis That Greenhouse Warming Is Causing a Global Increase in Hurricane Intensity. Bull. Amer. Met. Soc., 87 (8), 1025-1037. http://webster.eas.gatech.edu/Papers/Webster2006d.pdf

For the past three years, I have been working towards understanding the dynamics of uncertainty at the climate science-policy interface. This research[3] has led me to question whether these dynamics are operating in a manner that is healthy for either the science or the policy process. The role of scientists should not be to develop political will to act by implicitly or explicitly hiding or simplifying the uncertainties behind a negotiated consensus. Greater openness about scientific uncertainties and ignorance, and more transparency about dissent and disagreement, would provide policymakers with a more complete picture of climate science and its limitations, and ensure that the science community, policymakers, and the public are better equipped to understand, respond and adapt to climate change.

If all other things remain equal, it is clear that adding more carbon dioxide to the atmosphere will warm the planet. However the real difficulty is that nothing remains equal, and reliable prediction of the impact of carbon dioxide on the climate requires that we understand natural climate variability properly. Until we understand natural climate variability better, we cannot reliably infer sensitivity to greenhouse gas forcing or understand its role in influencing extreme weather events. Natural climate variability refers to forcing from the sun, volcanic eruptions and natural internal variability associated with chaotic interactions between the atmosphere and ocean. The most familiar mode of natural internal variability is El Nino/La Nino. On longer multi-decadal time scales, there is a network of atmospheric and oceanic circulation regimes, including the Atlantic Multidecadal Oscillation and the Pacific Decadal Oscillation. While 20th century climate change is most often explained in terms of external forcing, with natural internal variability providing high frequency 'noise,' the role of large multidecadal oscillations is receiving increasing attention. Further complicating this interpretation are new hypotheses whereby the external forcing projects onto the modes of natural internal variability, producing 'shifts' in the climate system.[4]

With this context, my testimony focuses on three scientific issues of central relevance to climate policy:

- Interpretation of the IPCC AR4 consensus conclusions on climate sensitivity and attribution of climate change in view of recent research and observations;
- Linkages between climate change and extreme weather; and
- Reasoning about climate uncertainty, including challenges and opportunities related to decision making under uncertainty

Climate sensitivity and attribution of climate change

The Intergovernmental Panel on Climate Change 4th Assessment report (IPCC AR4) published in 2007 made the following key statements in the Summary for Policy Makers[5]:

> *"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."* (p. 5)

> *"Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations"* (p. 10)

> *"For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emissions scenarios."* (p. 12)

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[3] Curry, JA and Webster PJ 2011: Climate science and the uncertainty monster. *Bull Amer Meteorol. Soc.*, 92, 1667-1682. http://journals.ametsoc.org/doi/pdf/10.1175/2011BAMS3139.1

[4] Tsonis, A et al. 2007: A new dynamical mechanism for major climate shifts. *Geophys. Res. Lett.*, 34, L13705. https://pantherfile.uwm.edu/aatsonis/www/2007GL030288.pdf

[5] IPCC AR4 Summary for Policy Makers http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html

The IPCC 5th Assessment Report (AR5) is well underway, and the *Working Group Report on The Physical Science Basis* will be published in September 2013[6]. Recent observations and analyses are illuminating the complexity of the climate system and challenging our understanding of the role of natural variability in contributing to recent climate change. The analysis provided below summarizes some of this recent research and key areas of controversy.

Key observations

As evidence that warming is unequivocal, the IPCC AR4 cites observations of global average air and ocean temperatures, ocean heat content, snow and ice melt, and sea level rise. In assessing this evidence, we need to consider the quality of these data in terms of their maturity as climate data records[7] and length of the records, so we can interpret appropriately the context of recent variations. To detect a human signal in recent climate change, we need to consider confounding factors associated with each of these data sets in assessing quality for purpose (including background natural variability). In context of these criteria, I focus my analysis here on the global surface temperature data and also sea ice extent data since 1979.

Surface temperature. Figure 1 shows the global average surface temperature anomalies through 2012, from the HadCRUT4 data set[8] (note: the GISTEMP and NOAA NCDC data sets show similar results).

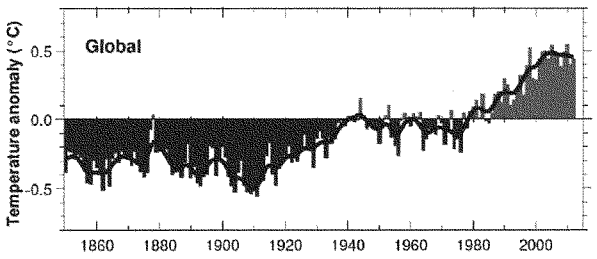

Figure 1. Global average surface temperature anomalies from the HadCRUT4 data set.
http://www.cru.uea.ac.uk/cru/data/temperature/HadCRUT4.pdf

Figure 1 shows a long-term increasing trend, and particularly during the last 25 years of the 20th century. However, since 1998 there has been no statistically significant increase in global surface temperature. While many engaged in the public discourse on this topic dismiss the significance of a hiatus in increasing global temperatures because of expected variations associated with natural variability, analyses of climate model simulations find very unlikely a plateau or period of cooling that extends beyond 17 years in the presence of human-induced global warming[9].

James Hansen has recently written:[10] "*The five-year mean global temperature has been flat for the last decade.*" Hansen interprets this as "*a combination of natural variability and a slow down in the growth*

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[6] http://www.ipcc.ch/activities/activities.shtml

[7] Bates, JJ and JL Privette (2012): A maturity model for assessing the completeness of climate data records. *EOS Trans. of Amer. Geophysical Union*, 93, p. 441. http://onlinelibrary.wiley.com/doi/10.1029/2012EO440006/abstract

[8] http://www.cru.uea.ac.uk/cru/data/temperature/HadCRUT4.pdf

[9] Santer, B. D., et al. (2011), Separating signal and noise in atmospheric temperature changes: The importance of timescale, J. Geophys. Res., 116, D22105, doi:10.1029/2011JD016263.

[10] Hansen, J., M Sato, R. Ruedy, 2013: Global Temperature Update Through 2012. http://www.columbia.edu/~jeh1/mailings/2013/20130115_Temperature2012.pdf

rate of net climate forcing." Hansen then suggests that *"global temperature will rise significantly in the next few years as the tropics moves inevitably to the next El Nino phase."* Others have suggested that the pause could last up to two decades[11] or even longer, owing to the transition to the cool phase of the Pacific Decadal Oscillation that is associated with a predominance of La Nina (cool) events.

Sea ice. The other data set that is of particular relevance in interpreting recent climate change is sea ice extent since 1979. While the Antarctic sea ice extent has increased over this period, the Arctic sea ice extent has declined substantially. The apparent paradox of increasing Antarctic sea ice extent in the presence of warming of the Southern Ocean was explained by Liu and Curry[12] who found an enhanced atmospheric hydrological cycle in the Southern Ocean that has resulted in an increase of the Antarctic sea ice for the past three decades through the reduced upward ocean heat transport and increased snowfall.

Figure 2 shows the time series of Arctic sea ice extent since 1979[13]. The most striking feature of this plot is the large decline of sea ice extent since about 2003, with record low values of minimum autumn sea ice extent set first in 2007 and then in 2012.

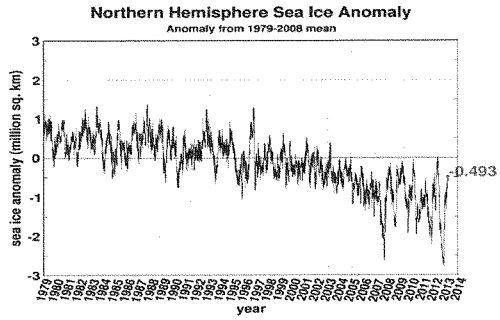

Figure 2. Northern Hemisphere sea ice anomalies
http://arctic.atmos.uiuc.edu/cryosphere/IMAGES/seaice.anomaly.arctic.png

It is difficult to untangle the relative roles of human-induced climate change versus natural variability in causing the Arctic sea ice decline. Using climate model simulations from the NCAR CCSM4, Kay et al.[14] inferred that approximately half (56%) of the observed rate of decline from 1979 to 2005 was externally (anthropogenically) forced, with the other half associated with natural internal variability. Stroeve et al.[15] used multiple climate model simulations from CMIP5 to infer that approximately 60% of the observed rate of decline from 1979–2011 is externally forced (compared to 41% determined from the earlier CMIP3 simulations). These simulations suggest an important role for natural variability as well as for human-induced climate change; further clarification of their relative roles awaits improved capabilities of the climate models in simulating natural internal variability, improved historical records of solar variability, and a longer record of sea ice extent.

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[11] http://www.wmo.int/wcc3/sessionsdb/documents/PS3_Latif.pdf

[12] Liu, J, JA Curry 2010: Accelerated warming in the Southern Ocean and its impacts on the hydrological cycle and sea ice. *PNAS*, 107, 14987-14992. http://www.pnas.org/content/107/34/14987.full

[13] http://arctic.atmos.uiuc.edu/cryosphere/IMAGES/seaice.anomaly.arctic.png (downloaded 2/23/13)

[14] Kay, J. E., M. M. Holland, and A. Jahn (2011), Inter-annual to multidecadal Arctic sea ice extent trends in a warming world, *Geophys. Res. Lett.*, 38, L15708, doi:10.1029/2011GL048008.

[15] Stroeve et al. 2012: Trends in Arctic Sea ice from CMIP5, CMIP3 and observations. *J. Geophys. Res.*, 39, L16502. http://www.uib.no/People/ngfhd/EarthClim/Publications/Papers/stroeve_etal_2012.pdf

Climate model - observation comparison

The fifth phase of the Coupled Model Intercomparison Project (CMIP5)[16] has produced a multi-model dataset that includes long-term simulations of twentieth-century climate and projections for the twenty-first century and beyond, as well as an entirely new suite of initialized decadal predictions focusing on recent decades and the future to year 2035. While providing the underlying basis for the forthcoming IPCC AR5, the CMIP5 model output has been made freely available to researchers through a distributed data archive[17]. An analysis provided by Ed Hawkins[18] at the University of Reading compares the global average surface temperatures from the HadCRUT4 dataset with 20 models from the CMIP5 simulations (Figure 3).

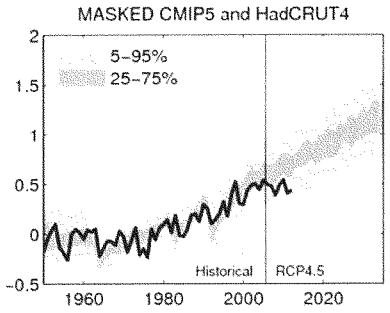

Figure 3. Comparison the global average surface temperatures from the HadCRUT4 dataset with 20 models from the CMIP5 simulations. http://www.climate-lab-book.ac.uk/2013/updated-comparison-of-simulations-and-observations/

The comparison in Figure 3 shows that observations particularly since 2005 are on the low end of the envelope that contains 90% of the climate model simulations. Extrapolation of the current flat trend would place the observations outside of the 90% envelope within a few years. While the observations remain within the substantial range of the climate model simulations, the trend in the model simulations is substantially larger than the observed trend over the past 15 years.

When considering possible physical reasons for the plateau since 1998, it is instructive to consider the previous mid-century plateau in global average surface temperature (Figure 1). The IPCC AR4 explained this previous plateau in the following way[19]: *"the cooling effects of sulphate aerosols may account for some of the lack of observational warming between 1950 and 1970, despite increasing greenhouse gas concentrations."* And *"variations in the Atlantic Multi-decadal Oscillation could account for up to 0.2°C peak-to-trough variability in NH mean decadal temperature."*

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[16] Taylor, Karl E., Ronald J. Stouffer, Gerald A. Meehl, 2012: An Overview of CMIP5 and the Experiment Design. *Bull. Amer. Meteor. Soc.*, **93**, 485–498. http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-11-00094.1

[17] http://cmip-pcmdi.llnl.gov/cmip5/

[18] http://www.climate-lab-book.ac.uk/2013/updated-comparison-of-simulations-and-observations/

[19] IPCC AR4 Chapter 9, p 686

Recent research on the impact of aerosols on radiative forcing of the climate has demonstrated that the overall cooling from aerosols is less than previously thought owing to a larger role for black carbon aerosols that have a net warming effect on climate[20].

With regards to multi-decadal natural internal variability, previous IPCC reports consider this issue primarily in context of detection of an anthropogenic warming signal above the background 'noise' of natural variability. The IPCC's attribution of the late 20th century warming has focused on external radiative forcing, and no explicit estimate of the contribution of natural internal variability to the warming was made. A recent paper by Tung and Zhou[21] suggests that the anthropogenic global warming trends might have been overestimated by a factor of two in the second half of the 20th century. They argue that a natural multidecadal oscillation of an average period of 70 years with significant amplitude of 0.3–0.4°C is superimposed on the secular warming trend, which accounts for 40% of the observed warming since the mid-20th century. Tung and Zhou identify this oscillation with the Atlantic Multidecadal Oscillation (AMO), although recent research[22] suggests a more complex multidecadal signal propagating through a network of synchronized climate indices. Tung and Zhou argue that not taking the AMO into account in predictions of future warming under various forcing scenarios may run the risk of over-estimating the warming for the next two to three decades, when the AMO is likely in its down phase.

The recent research on natural internal variability and black carbon aerosols, combined with ongoing plateau in global average surface temperature, suggests that the AR4 estimates of climate sensitivity to doubling CO2 may be too high, with implications for the attribution of late 20th century warming and projections of 21st century warming. The IPCC AR4 conclusion on climate sensitivity is stated as:

> *"The equilibrium climate sensitivity. . . is likely to be in the range 2°C to 4.5°C with a best estimate of about 3°C and is very unlikely to be less than 1.5°C. Values higher than 4.5°C cannot be excluded. ."* [23]

This estimate of equilibrium climate sensitivity is not easily reconciled with recent forcing estimates and observational data. There is increasing support for values of climate sensitivity around or below 2°C[24,25,26]. The meta-uncertainty of these estimates remains high owing to inadequacies in the methods used to determine sensitivity from observations and models[27]. If the climate models are running too 'hot' in terms of predicting climate sensitivity that is too high, what are the possible problems with the models that might contribute to this? While the direct forcing from greenhouse gases is well understood, possible problems are associated with the magnitudes of the water vapor feedback and the cloud feedback. The cloud-radiative feedback is one of the most uncertain elements of climate models[28]; even the sign is uncertain, although most climate models produce a positive cloud-radiative feedback (warming effect).

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[20] Bond et al. 2013: Bounding the role of black carbon in the climate system: A scientific assessment. *J. Geophys. Res.* http://onlinelibrary.wiley.com/doi/10.1002/jgrd.50171/abstract

[21] Tung, KK and J Zhou, 2013: Using data to attribute episodes of warming and cooling in instrumental records. *PNAS* http://www.pnas.org/content/early/2013/01/22/1212471110.abstract

[22] Wyatt, MG and JM Peters 2012: A secularly varying hemispheric climate-signal propagation. *SpringerPlus*, 1:68, doi:10.1186/2193-1801-1-68. http://www.springerplus.com/content/pdf/2193-1801-1-68.pdf

[23] IPCC AR4 Summary for Policy Makers, op. cit., p. 12.

[24] M. J. Ring, D. Lindner, E. F. Cross and M. E. Schlesinger, "Causes of the Global Warming Observed since the 19th Century," *Atmospheric and Climate Sciences*, Vol. 2 No. 4, 2012, pp. 401-415. http://www.scirp.org/journal/PaperInformation.aspx?paperID=24283

[25] Lewis, N. 2013: An objective Bayesian, improved approach for applying optimal fingerprint techniques to estimate climate sensitivity. *J. Climate*, doi: http://dx.doi.org/10.1175/JCLI-D-12-00473.1

[26] Masters, T. 2013: Observational estimate of climate sensitivity from changes in the rate of ocean heat uptake and comparison to CMIP5 models. *Climate Dynamics*, in press. http://link.springer.com/article/10.1007/s00382-013-1770-4

[27] Olson, R. et al. 2013: What is the effect of unresolved internal climate variability on climate sensitivity estimates? *J. Geophysical Sciences*, in press. http://onlinelibrary.wiley.com/doi/10.1002/jgrd.50390/abstract

[28] IPCC AR4 Summary for Policy Makers, op. cit., p 12.

Summary evaluation

The key conclusion of the IPCC AR4 is:

> *"Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."*[29]

So what is the evidence for, and against, a dominant role in the climate since the mid-20th century of increasing human-induced greenhouse gas concentrations, and what are the major uncertainties? Below is my summary interpretation of the available evidence.

Evidence for:

- Long-term trend of increasing surface temperatures, for more than a century.
- Theoretical support for warming as greenhouse gas concentration increases.
- Long-term trend of increasing ocean heat content[30], although the trend for the past 10 years has been small in the upper 700 m of the ocean[31].
- Decline in Arctic sea ice since 1979, with record autumn minimum in 2012.
- Sea level rise since 1961, although multi-decadal variability and confounding factors such as coastal land use and geologic process hamper interpretation of these data.[32]
- Results from climate model simulations.

Evidence against:

- No significant increase in globally averaged temperature for the past 15 years.
- Lack of a consistent and convincing attribution argument for the warming from 1910-1940 and the plateau from the 1940s to the 1970s.
- Growing realization that multidecadal natural internal variability is of higher amplitude than previously accounted for in IPCC attribution analyses.

There are major uncertainties in many of the key observational data sets, particularly prior to 1980. There are also major uncertainties in climate models, particularly with regards to the treatments of clouds, solar indirect effects and the coupled multidecadal oscillations between the ocean and atmosphere. Further, there are meta-uncertainties regarding the methods used to make arguments about attribution of climate change and determine sensitivity to increasing greenhouse gases. And finally, climate models are apparently incapable of simulating emergent phenomena such as abrupt climate change.

In light of these uncertainties, what can we say about the future climate of the 21st century? Most scientists anticipate a decrease in solar forcing in the coming decades, but noting the absence of understanding the solar indirect effects on climate, this is not expected to dominate climate change in the 21st century[33]. If the climate shifts hypothesis[34] is correct, then the current flat trend in global surface temperatures may continue for another decade or two, with a resumption of warming at some point during mid-century. The amount of warming from greenhouse gases depends both on the amount of greenhouse gases that are emitted as well as the climate sensitivity to the greenhouse gases, both of which are associated with substantial uncertainties.

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[29] IPCC AR4 Summary for Policy Makers, op. cit., p 10.

[30] Balmaseda et al. 2013: Distinctive climate signals in reanalysis of global ocean heat content. *J. Geophys. Res.*, in press. http://onlinelibrary.wiley.com/doi/10.1002/grl.50382/abstract

[31] http://oceans.pmel.noaa.gov

[32] Gregory et al. 2012: Twentieth-century global mean sea-level rise: is the whole greater than the sum of the parts? *J. Climate*, http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-12-00319.1

[33] G. S., M. Lockwood, and P. A. Stott (2012), What influence will future solar activity changes over the 21st century have on projected global near-surface temperature changes? *J. Geophys. Res.*, 117, D05103,

[34] Tsonis, A et al. 2007: op. cit.

Climate change and extreme weather

The prospect of increased frequency or severity of extreme weather in a warmer climate is potentially the most serious near term impact of climate change. Metaphors such as climate change 'loading the dice' for severe weather or causing 'weather on steroids' are frequently used to communicate an elevated probability of extreme weather events as a result of human-caused climate change. Because of their large socioeconomic impacts, weather catastrophes act as focusing events for the public in the politics surrounding the climate change debate. The occurrence of apparently unusual extreme weather events over the past decade has been used as an argument for action to reduce greenhouse gases in the atmosphere. In his recent State of the Union speech, President Obama made the following statement:

> *"But for the sake of our children and our future, we must do more to combat climate change. Yes, it's true that no single event makes a trend . . . Heat waves, droughts, wildfires, and floods – all are now more frequent and intense. We can choose to believe that Superstorm Sandy, and the most severe drought in decades, and the worst wildfires some states have ever seen were all just a freak coincidence. Or we can choose to believe in the overwhelming judgment of science – and act before it's too late."*[35]

Trenberth[36] has argued that climate change is affecting all weather now, because the background conditions have changed as a result human-caused global warming. I don't disagree with this statement; however there is no *prima facie* reason to think that global warming will make most extreme weather events more frequent or more severe. To understand the extent to which anthropogenic global warming might be contributing to individual or collections of extreme events, scientists need to demonstrate that the current extreme weather events are unusual in context of the historical record. Extreme events are by definition rare, and the rarer the event the more difficult it is to identify long-term changes from relatively short data records.

In 2012, the IPCC published a *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX). Key findings from the SREX[37] are cited below:

> ***There is evidence from observations gathered since 1950 of change in some extremes. Confidence in observed changes in extremes depends on the quality and quantity of data and the availability of studies analyzing these data, which vary across regions and for different extremes. Assigning 'low confidence' in observed changes in a specific extreme on regional or global scales neither implies nor excludes the possibility of changes in this extreme.*** *In many (but not all) regions over the globe with sufficient data, there is medium confidence that the length or number of warm spells or heat waves has increased. There have been statistically significant trends in the number of heavy precipitation events in some regions. It is likely that more of these regions have experienced increases than decreases, although there are strong regional and subregional variations in these trends. There is low confidence in any observed long-term (i.e., 40 years or more) increases in tropical cyclone activity (i.e., intensity, frequency, duration), after accounting for past changes in observing capabilities. There is low confidence in observed trends in small spatial-scale phenomena such as tornadoes and hail because of data inhomogeneities and inadequacies in monitoring systems. There is medium confidence that some regions of the world have experienced more intense and longer droughts, in particular in southern Europe and West Africa, but in some regions droughts have become less frequent, less intense, or shorter, for*

[35] http://www.whitehouse.gov/state-of-the-union-2013
[36] Trenberth, KE 2012: Framing the way to relate climate extremes to climate change. *Climatic Change*, 115, 283-290. http://link.springer.com/article/10.1007%2Fs10584-%C2%AD-012-%C2%AD-0441-%C2%AD-5?LI=true#page-1
[37] IPCC SREX Summary for Policy Makers, http://ipcc-wg2.gov/SREX/images/uploads/SREX-SPMbrochure_FINAL.pdf

example, in central North America and northwestern Australia. There is limited to medium evidence available to assess climate-driven observed changes in the magnitude and frequency of floods at regional scales because the available instrumental records of floods at gauge stations are limited in space and time, and because of confounding effects of changes in land use and engineering. Furthermore, there is low agreement in this evidence, and thus overall low confidence at the global scale regarding even the sign of these changes. It is likely that there has been an increase in extreme coastal high water related to increases in mean sea level.

There is evidence that some extremes have changed as a result of anthropogenic influences, including increases in atmospheric concentrations of greenhouse gases. *It is likely that anthropogenic influences have led to warming of extreme daily minimum and maximum temperatures at the global scale. There is medium confidence that anthropogenic influences have contributed to intensification of extreme precipitation at the global scale. It is likely that there has been an anthropogenic influence on increasing extreme coastal high water due to an increase in mean sea level."*

While there is limited observational evidence for an increase in the frequency or intensity of most types of extreme weather events, the SREX finds that climate models project increases in frequency and/or intensity of many types of extreme weather events by the end of the 21st century. However, climate models do a poor job of simulating the variability and intensity of rainfall even in the present climate, and also do not resolve tropical cyclones adequately. Further, climate models do not adequately simulate the modes of natural internal variability. *Nature* recently reported:

At a workshop last week in Oxford, UK, convened by the Attribution of Climate-related Events group — a loose coalition of scientists from both sides of the Atlantic — some speakers questioned whether event attribution was possible at all. It currently rests on a comparison of the probability of an observed weather event in the real world with that of the 'same' event in a hypothetical world without global warming. One critic argued that, given the insufficient observational data and the coarse and mathematically far-from-perfect climate models used to generate attribution claims, they are unjustifiably speculative, basically unverifiable and better not made at all . . . Better models are needed before exceptional events can be reliably linked to global warming."[38]

Attempts to attribute individual extreme weather events, or collections of extreme weather events, may be fundamentally ill-posed in the context of the complex, chaotic climate system. In addition to the substantial difficulties and problems associated with attributing changes in the average climate to natural variability versus anthropogenic forcing, attribution of extreme weather events is further complicated by their rarity and their dependence on weather regimes and internal multi-decadal oscillations that are simulated poorly by climate models. Given these challenges, why is attribution of extreme events deemed important by climate scientists? The *Nature* summary on the Oxford workshop states:

None of the industry and government experts at the workshop could think of any concrete example in which an attribution [of extreme weather events] might inform business or political decision-making. Especially in poor countries, the losses arising from extreme weather have often as much to do with poverty, poor health and government corruption as with a change in climate. These caveats do not mean that event attribution is a lost cause. But they are a reminder that designers of climate services must think very clearly about how others might want to use the knowledge that climate scientists produce.

[38] Nature editorial: Extreme Weather, 2012: *Nature* **489,** 335–336. http://www.nature.com/news/extreme-weather-1.11428

Preliminary damage estimates rank Hurricane Sandy as the 2nd costliest Atlantic hurricane, only behind Hurricane Katrina. When Sandy made landfall, it was categorized as a post-tropical cyclone with winds equivalent to a Category 1 hurricane. Sandy's 13 ft storm surge arose from a combination of a very large horizontal extent of the storm plus high tide conditions. Climate scientists and meteorologists continue to argue about what role human-induced climate change might have played in Sandy, but as described above, there is no obvious link to human-caused climate change and attempts at such attribution may be fundamentally an ill-posed problem. Hurricane Sandy, along with Hurricane Katrina and the hurricanes that struck Florida during 2004 and 2005, have focused debate on whether climate change portends more frequent or more severe hurricane impacts. I have provided Congressional testimony twice on the subject of hurricanes and global warming[39] and recently wrote an extended assessment report on the topic.[40]

The current elevated hurricane activity in the North Atlantic is associated with the warm phase of the Atlantic Multidecadal Oscillation, which could continue for another decade or two. The recent transition to the cool phase of the Pacific Oscillation is associated with a greater frequency of La Nina events, which are associated with elevated hurricane activity and a preference for Atlantic landfalls (relative to Gulf landfalls).[41] With regards to possible impacts from human-induced climate change, an increase in hurricane intensity has been observed over the past several decades, although it is not easily separated from the large signal from the Atlantic Multidecadal Oscillation. The extension of the tropical Atlantic warm pool eastward towards Africa may be attributable to anthropogenic global warming[42]; the main impact of this extended warm pool seems to be a tendency for hurricanes to form further east in the Atlantic and recurve northwards, reducing the number of U.S. landfalls.

With regards to the perception (and damage statistics) that severe weather events seem more frequent and more severe over the past decade, there are several factors in play. The first is the increasing vulnerability and exposure associated with increasing concentration of wealth in coastal and other disaster-prone regions. The second factor is natural climate variability. Apart from a possible impact from human-induced climate change, many extreme weather and climate events have documented relationships with natural climate variability, notably El Niño/La Niña, the Atlantic Multidecadal Oscillation (AMO), and Pacific Decadal Oscillation (PDO). We are currently in the warm phase of the AMO and the cool phase of the PDO. The previous analogue for this regime was the 1950s, or more specifically the period from 1946 to 1964. This period was also very active in terms of Atlantic hurricanes,[43] especially with regards to U.S. landfalling major hurricanes. Drought in the U.S. is more frequent during the warm phase of the AMO, with drought in the U.S. southwest and Texas being more common during the cool phase of the PDO.[44] The analogy of the last decade with the previous regime of warm AMO/cool PDO in terms of extreme weather/climate events is imperfect, because global temperatures are about 1°F warmer and Arctic sea ice extent has decreased. The decrease in autumn sea ice has recently been associated with changes in atmospheric circulation patterns and an increase in winter snowfall in North America and Eurasia.[45]

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[39] http://curry.eas.gatech.edu/climate/pdf/testimony-curry.pdf; http://www.eas.gatech.edu/files/Curry_Energy.pdf

[40] http://judithcurry.com/2010/09/13/hurricanes-and-global-warming-5-years-post-katrina/

[41] Kim, H.M., P. J. Webster and J. A. Curry, 2009: Impact of shifting patterns of Pacific Ocean warming on the frequency and tracks of North Atlantic tropical cyclones. *Science*, 325, 77-80. http://webster.eas.gatech.edu/Papers/KimWebsterCurry_Science_2009.pdf

[42] Hoyos, C. D. and Webster, P. J., 2011: Evolution of the tropical warm pool: Past, present and future. *Clim. Dyn.* doi: 10.1007/s00382-011-1181-3. http://webster.eas.gatech.edu/Papers/Hoyos_Webster2011.pdf

[43] http://www.eas.gatech.edu/files/ins_tampa_09.pdf

[44] McCabe G J et al. 2004: *PNAS*, 101, 4136-4141.

[45] Liu, J, JA Curry et al., 2011: Impact of declining Arctic sea ice on winter snowfall. *PNAS*, http://curryja.files.wordpress.com/2012/03/pnas.pdf

Reasoning about climate uncertainty

How to reason about uncertainties in the complex climate system and its model simulations is neither simple nor obvious. Scientific debates involve controversies over the value and importance of particular classes of evidence and disagreement about the appropriate logical framework for assessing the evidence.

The IPCC characterization of uncertainty is based upon a consensus building process that is an exercise in collective judgment in areas of uncertain knowledge. The general reasoning underlying the IPCC's arguments for anthropogenic climate change combines a compilation of evidence with subjective Bayesian reasoning. Given the complexity of the climate problem, expert judgments about uncertainty and confidence levels are made by the IPCC on issues that are dominated by unquantifiable uncertainties. I have argued in a paper entitled *Reasoning About Climate Uncertainty*[46] that biases can abound when reasoning and making judgments about such a complex problem, through weighting of evidence and excessive reliance on a particular piece of evidence, the presence of cognitive biases in heuristics, failure to account for indeterminacy and ignorance, and logical fallacies and errors including circular reasoning. Further, the consensus building process itself can be a source of bias.

Identifying the most important uncertainties and introducing a more objective assessment of confidence levels requires introducing a more disciplined logic into the climate change assessment process. Improved understanding and characterization of uncertainty and ignorance would promote a better overall understanding of the science and how to best target resources to improve understanding. A concerted effort is needed to identify better ways of exploring and characterizing uncertainty, reasoning about uncertainty, and eliminating bias from the consensus building process itself. There are some encouraging efforts in this direction, including a special issue of the journal *Climatic Change.*[47] There is also a rapidly growing effort in the area of uncertainty quantification and management with regards to climate models and climate model simulations.

No consensus on consensus

With substantial uncertainties in observations, models and our understanding of processes such as natural variability, along with challenges of reasoning about uncertainty in the complex climate system, there would seem to be plenty of scope for disagreement among scientists. Nevertheless, the IPCC consensus about dangerous anthropogenic climate change is portrayed as nearly total among scientists with expertise and prominence in the field of climate science, and the IPCC consensus has been endorsed by the relevant national and international science academies and scientific societies. I recently authored a paper entitled *Climate Change: No Consensus on Consensus*[48] that explores the history and consequences of the IPCC's scientific consensus building activities, which provides the basis for my comments here.

To understand the role of scientific consensus in policy making, it is important to understand the policy context for the information on dangerous climate change and the way the political process views uncertainty. The mandate of the IPCC is to provide policy-relevant information to policy makers involved in the UN Framework Convention on Climate Change (UNFCCC). Using the precautionary principle, the UNFCCC established a goal of avoiding dangerous climate change by stabilization of the concentrations

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[46] Curry, JA 2011: Reasoning About Climate Uncertainty. *Climatic Change,* 108, 723-732. http://link.springer.com/article/10.1007%2Fs10584-011-0180-z

[47] Yohe, G and M. Oppenheimer, 2011: Evaluation, characterization and communication of uncertainty by the intergovernmental panel on climate change – an introductory essay. *Climatic Change,* 108, 629-639. http://link.springer.com/article/10.1007%2Fs10584-011-0176-8

[48] Curry, JA and PJ Webster 2013: No consensus on consensus. *CAB Reviews,* 8, 001. http://judithcurry.com/2012/10/28/climate-change-no-consensus-on-consensus/

of atmospheric greenhouse gases. The IPCC scientific assessments play a primary role in legitimizing national and international policies aimed at reducing greenhouse gas emissions. The main practical objective of the IPCC has been to assess whether there is sufficient certainty in the science so as to trigger political action to reduce greenhouse gas emissions, and to optimize stabilization targets using climate models. This objective has led to the IPCC assessments being framed around identifying anthropogenic influences on climate, dangerous environmental and socio-economic impacts of climate change, and stabilization of CO_2 concentrations in the atmosphere.

The strategy adopted by the UNFCCC/IPCC is based on the linear model of expertise, whereby more scientific research leads to more reliable knowledge and less uncertainty, and the scientific knowledge then forms the basis for a political consensus leading to meaningful action. In the linear model, the key question is whether scientific knowledge is certain enough to compel action. Given the substantial uncertainties in climate science, the IPCC has arguably adopted a 'speaking consensus to power' approach[49] that attempts to mediate uncertainty and dissent into a consensus. The 'speaking consensus to power' strategy acknowledges that available knowledge is inconclusive, and uses consensus as a proxy for truth through a negotiated interpretation of the scientific evidence.

The growing implications of the complexity of the climate change problem and its potential solutions are becoming increasingly apparent, highlighting the inadequacies of the 'consensus to power' approach for decision making on the complex issues associated with climate change.

Decision making under 'deep uncertainty'

My particular interest in the topic of decision making under uncertainty is to understand the dynamics of uncertainty at the climate science-policy interface. I am questioning whether these dynamics are operating in a manner that is healthy for either the science or the policy process, and whether climate science can more usefully support the policy process.

When uncertainty is well characterized and there is confidence in the model structure, classical decision analysis can provide statistically optimal strategies for decision makers. When uncertainty is not well characterized and there is concern about 'known unknowns' and 'unknown unknowns,' there is increasing danger of getting the wrong answer and optimizing for the wrong target. Given the 'messy wickedness' of the climate change problem with irreducible uncertainties and substantial ignorance, reducing the uncertainty isn't viable, but not acting could be associated with catastrophic impacts. While the precautionary principle states that scientific uncertainty should not preclude preventative measures, greater levels of certainty are usually more conducive to motivating precautionary measures. In this context, making a scientific argument that uncertainty is underestimated and the consensus is overconfident is regarded as making a political statement to sow doubt and so delay action in taking precautionary measures.[50] If discussing uncertainty and engaging with skeptics is regarded as a political statement or as 'heresy'[51] then it seems to me that something is wrong with the science-policy interface and the decision-analytic framework that is being used.

In context of decision making, 'deep uncertainty'[52] refers to: situations in which the phenomena are still only poorly understood and experts do not know or cannot agree on models that relate key forces that

[49] Van der Sluijs, J, 2012: Uncertainty and dissent in climate risk assessment: a postnormal perspective. *Nature and Culture*, 7, 174–195

[50] Oreskes, N. and E.M. Conway (2010) *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming.* Bloomsbury Press, 368 pp.

[51] Climate Heretic: Judith Curry Turns on her Colleagues. Scientific American, 10/23/10 http://www.scientificamerican.com/article.cfm?id=climate-heretic

[52] Bammer, G and M Smithson 2008: *Uncertainty and Risk: Multidisciplinary Perspectives.* Taylor & Francis, 382 pp.

shape the future; modeling and subjective judgments are used rather than estimates based upon previous experience of actual events and outcomes; and experts cannot agree on the value of alternative outcomes. The climate change problem arguably meets all three of these criteria.

Rather than choosing an optimal policy based on a scientific consensus, decision makers can design robust and flexible policy strategies that account for uncertainty, ignorance and dissent. Robust strategies formally consider uncertainty, whereby decision makers seek to reduce the range of possible scenarios over which the strategy performs poorly. Flexible strategies are adaptive, and can be quickly adjusted to advancing scientific insights. Under conditions of deep uncertainty, the following options are open to decision makers[53]:

- Delay in order to gather more information and in the hope of reducing uncertainties
- Enlarge the knowledge base for decisions through broader perspectives
- Invoke the precautionary principle
- Adaptive management
- Build a resilient society.

Each of these strategies incorporates information about uncertainty into the decision making process, albeit in different ways. In the past, the climate policy choices have been framed as a choice between delaying until uncertainties are reduced versus invoking the precautionary principle aimed at emission stabilization targets determined largely by climate models. The other options are receiving increasing attention in policy deliberations. The World Bank has a recent paper entitled *Investment decision making under deep uncertainty – application to climate change*[54] that summarizes existing decision-making methodologies that are able to deal with the deep uncertainty associated with climate change: cost-benefit analysis under uncertainty, cost-benefit analysis with real options, robust decision making, and Climate Informed Decision Analysis. The World Bank document describes Climate Informed Decision Analysis (CIDA) in the following way:

> *"Climate Informed Decision Analysis is a method of incorporating climate change information into the decision-making process, by first identifying which sets of climate changes would affect the project and then determining the likelihood of those sets. As a process committed to acceptance of deep uncertainties, CIDA does not attempt to reduce uncertainties or make predictions, but rather determine which decision options are robust to a variety of plausible futures."* (p 24)

The role of climate science in CIDA is to determine the plausibility of relevant groups of climate conditions that would affect the project. This can be accomplished by sensitivity analyses using climate models, analysis of historical and paleo- climate data, and the use of statistical models. The World Bank document describes the use of climate scenarios:

> *"Climate scenarios can be generated parametrically or stochastically to explore uncertainty in climate variables that affect the system of interest. This allows sampling changes in climate that include but are not constrained by the range of GCM [climate model] projections. The definition of scenarios can be developed as part of a stakeholder-driven, negotiated process, and climate projections can be used in this process. Alternatively, a very wide range of climate alterations can be developed independent of their plausibility and used to identify risks. For scenarios in which the climate consequences exceed coping thresholds, it is then fruitful to evaluate the plausibility of the scenarios. Climate projections, paleo-climate reconstructions, and subjective climate knowledge could all inform such discussions."*

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[53] ibid.
[54] http://elibrary.worldbank.org/content/workingpaper/10.1596/1813-9450-6193

Conclusion

The climate community has worked for more than 20 years to establish a scientific consensus on anthropogenic climate change. The IPCC consensus building process arguably played a useful role in the early synthesis of the scientific knowledge. However, I have argued that the ongoing scientific consensus seeking process has had the unintended consequence of oversimplifying both the problem and its solution, introducing biases into the both the science and related decision making processes. The growing implications of the messy wickedness of the climate change problem are becoming increasingly apparent, highlighting the inadequacies of the 'consensus to power' approach for decision making on the complex issues associated with climate change.

The politicization of climate change presents daunting challenges to climate science and scientists. In my assessment, the single most important actions that are needed with regards to climate science – particularly in context of assessments for policymakers – is explicit reflection on uncertainties, ambiguities and areas of ignorance (both known and unknown unknowns) and more openness for dissent. Natural internal variability is a topic of particular importance over which there is considerable disagreement. Disagreement and debate is the soul of the scientific frontier, which is where much of climate science lies. Greater openness about scientific uncertainties and ignorance, and more transparency about dissent and disagreement, would provide policymakers with a more complete picture of climate science and its limitations. When working with policy makers and communicators, scientists should not fall into the trap of acceding to inappropriate demands for certainty; the intrinsic limitations of the knowledge base need to be properly assessed and presented to decision makers. The role of scientists should not be to develop political will to act by hiding or simplifying the uncertainties, either explicitly or implicitly, behind a negotiated consensus.

Increasingly, arguments are being made to abandon the scientific consensus seeking approach[55] in favor of open debate and discussion of a broad range of policy options that stimulate local and regional solutions to the multifaceted and interrelated issues surrounding climate change. There are frameworks for decision making under deep uncertainty that accept uncertainty and dissent as key elements of the decision making process. Rather than choosing an optimal policy based on a scientific consensus, decision makers can design robust and flexible policy strategies that account for uncertainty, ignorance and dissent. Robust strategies formally consider uncertainty, whereby decision makers seek to reduce the range of possible scenarios over which the strategy performs poorly.

The decision making framework referred to as Climate Informed Decision Analysis has the potential to provide a more useful role for climate scientists and an expanded role for a broader range of different types of climate information. The outcome of CIDA is not a single optimal decision, but a decision matrix that reflects stakeholder concerns and reveals which specific dangers might be associated with specific decisions and supports improved cost-benefit analyses. This decision making framework, along with other frameworks for decision making under deep uncertainty, is more democratic and transparent and avoids the hubris of pretending to know what will happen in the future.

Returning to my experiences with decision makers in using weather and seasonal climate forecasts, I would like to remind that uncertainty about the future climate is a two-edged sword. There are two situations to avoid: i) issuing a highly confident statement about the future that turns out to be wrong; and ii) missing the possibility of an extreme, catastrophic outcome. Avoiding both of these situations requires much deeper and better assessment of uncertainties and areas of ignorance, as well as creating a broader range of future scenarios than is currently provided by climate models.

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[55] Hulme, M., 2013: Lessons from the IPCC: Do Scientific Assessments Need to be Consensual to be Authoritative? http://www.csap.cam.ac.uk/events/future-directions-scientific-advice-whitehall/

Short Biography

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Dr. Judith Curry is Professor and Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology and President of Climate Forecast Applications Network (CFAN). Dr. Curry received a Ph.D. in atmospheric science from the University of Chicago in 1982. Prior to joining the faculty at Georgia Tech, she held faculty positions at the University of Colorado, Penn State University and Purdue University. Dr. Curry's research interests span a variety of topics in climate; current interests include air/sea interactions, climate feedback processes associated with clouds and sea ice, and the climate dynamics of hurricanes. She is a prominent public spokesperson on issues associated with the integrity of climate science, and has recently launched the weblog Climate Etc. judithcurry.com. Dr. Curry currently serves on the NASA Advisory Council Earth Science Subcommittee and the DOE Biological and Environmental Research Advisory Committee, and has recently served on the National Academies Climate Research Committee and the Space Studies Board and the NOAA Climate Working Group. Dr. Curry is a Fellow of the American Meteorological Society, the American Association for the Advancement of Science, and the American Geophysical Union.

Financial declaration

Funding sources for Curry's research have included NSF, NASA, NOAA, DOD and DOE. Recent contracts for CFAN include a DOE contract to develop extended range regional wind power forecasts and a DOD contract to predict extreme events associated with climate variability/change having implications for regional stability. CFAN contracts with private sector and other non-governmental organizations include energy and power companies, reinsurance companies, other weather service providers, the Natural Resource Defense Council and the World Bank. Specifically with regards to the energy and power companies, these contracts are for medium-range (days to weeks) forecasts of hurricane activity and landfall impacts. CFAN has one contract with an energy company that also includes medium-range forecasts of energy demand (temperature), hydropower generation, and wind power generation. CFAN has not received any funds from energy companies related to climate change or any topic related to this testimony.

For more information:

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Dr. Judith Curry is Professor and Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology and President of Climate Forecast Applications Network (CFAN). Dr. Curry received a Ph.D. in atmospheric science from the University of Chicago in 1982. Prior to joining the faculty at Georgia Tech, she held faculty positions at the University of Colorado, Penn State University and Purdue University. Dr. Curry's research interests span a variety of topics in climate; current interests include air/sea interactions, climate feedback processes associated with clouds and sea ice, and the climate dynamics of hurricanes. She is a prominent public spokesperson on issues associated with the integrity of climate science, and has recently launched the weblog Climate Etc. judithcurry.com. Dr. Curry currently serves on the NASA Advisory Council Earth Science Subcommittee and the DOE Biological and Environmental Research Advisory Committee, and has recently served on the National Academies Climate Research Committee and the Space Studies Board and the NOAA Climate Working Group. Dr. Curry is a Fellow of the American Meteorological Society, the American Association for the Advancement of Science, and the American Geophysical Union.

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Chairman STEWART. Thank you, Dr. Curry.
Dr. Chameides, please, sir, for five minutes.

TESTIMONY OF DR. WILLIAM CHAMEIDES,
DEAN AND PROFESSOR,
NICHOLAS SCHOOL OF THE ENVIRONMENT,
DUKE UNIVERSITY

Dr. CHAMEIDES. Thank you, Chairman Stewart, Ranking Member Bonamici, Chair of the Full Committee Smith, and other Members of the Subcommittee for the opportunity to testify today. My name is Bill Chameides. I am the dean of the Nicholas School of the Environment, and a member of the U.S. National Academy of Sciences. I am atmospheric scientist who has focused principally on the chemistry of the lower atmosphere, trying to understand the causes of environmental change, and identify pathways towards a more sustainable future.

My main message today is the risks posed by human caused climate change are significant, and warrant timely action to minimize these risks. Yes, there are uncertainties, but these uncertainties do not justify inaction. What they do suggest is that our response should be a flexible one that allows for course corrections as new information and knowledge comes available. Much of what we know about the climate is the product of more than 100 years of research, founded on the most basic laws of science, and grounded by ever improving observations of the climate system. Thermometer measurements show that the Earth's average surface temperature has risen substantially over the past century. Much has been made of the so-called recent pause, or hiatus, in global warming, but we should keep the following context in mind. Present day temperatures are anomalously high. The last decade was the warmest on record. Nine of the 10 warmest years on record occurred since 2001, and 2010 and 2005 were the warmest and second warmest years on record, respectively.

Significantly, the frequencies of extremely hot summer days has increased by more than a factor of 10 globally. The climate in the United States has become more variable and extreme. Over the past 50 years we have seen an increase in prolonged stretches of excessively high temperatures, more heavy downpours, and in some regions, more severe droughts. The preponderance of evidence suggests that most of the recent decadal scale warming can be attributed to fossil fuel burning and other human activities that release carbon dioxide and other heat trapping greenhouse gases into the atmosphere.

I have noted that Dr. Curry, in her written testimony, states that a 2012 paper by Tonen Xiao suggests that the anthropogenic global warming trends might have been overestimated by a factor of two in the second half of the 20th century. Now, Dr. Curry has been a colleague of mine for many years. I respect her as a scientist. In fact, I was—I enthusiastically helped recruit her to her present position at Georgia Tech. But I find some of her statements to be problematic, and this is one of them. In the case of the Tonen Xiao paper, it is germane and important to also note that one of the implications of their result is that virtually all of the net warming over the past 100 years can be attributed to human activities.

Human caused climate changes and impacts will continue for many decades, even centuries, however, the precise nature of these impacts cannot be predicted with great certainty. But we do know that the risks are considerable, and we haven't discussed at all the problem of ocean acidification from CO_2, which is a virtual certainty.

So how should we, as a Nation, respond? There is, of course, room for debate about what climate policies should be implemented, but uncertainty is not a reason for inaction. We, as individuals, and as a society, often act in the face of uncertainty. I, for example, cannot predict if, let alone when, there will be a fire in my house, but I pay for fire insurance. Similarly, in the face of uncertain but substantial risk from climate change, it is prudent to develop and implement a risk based flexible response to the climate change challenge. Such a response should have the following elements, reducing greenhouse gas emissions, mobilizing—investing in science, technology, and information systems, participating in international climate change efforts, and coordinating a national response.

Let me highlight a few of these, and more details are in my written testimony. The nation will need to reduce greenhouse gas emissions. The magnitude and speed of emissions reductions depends, of course, on societal judgments about how much risk is acceptable, and what cost. However, given the long lifetime associated with infrastructure for energy production, and the potential for irreversible climate change, the most effective strategy is to begin ramping down emissions as soon as possible.

Because we cannot predict the exact path climate change will take, we cannot prescribe a set of climate policies today that we know will be optimum for decades to come, and so we need an iterative risk management approach that systematically and continuously identifies risks, advances a portfolio of actions that reduce risks, and revises responses in light of new knowledge. And it is my impression that, on this issue, Dr. Curry and I are in agreement.

America has choices to make about climate change, choices that we must face in the face of uncertainty, but also risks that are growing with every new ton of greenhouse gases we emit. We cannot avoid these choices. Bear in mind that making a choice to do nothing is, in fact, a choice. It is a choice that our children, and their children, and their children after them, will face increased risks from human induced climate change.

Thank you very much.

[The prepared statement of Mr. Chameides follows:]

United States House of Representatives
Committee on Science, Space and Technology
Subcommittee on Environment

Hearing on Policy-Relevant Climate Issues in Context
April 25, 2013

Testimony

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Introduction

Thank you, Chairman Stewart, Ranking Member Bonamici and other members of the Subcommittee for the opportunity to testify on the very important topic of climate science and policy options to address climate change. My name is Bill Chameides and I am the Dean of the Nicholas School of the Environment and Nicholas Professor of the Environment at Duke University and a member of the U.S. National Academy of Sciences. I am by training an atmospheric scientist, having spent much of my research career studying the chemistry of the lower atmosphere and the impacts of regional air pollution, trying to understand the causes of environmental change and identify pathways toward a more sustainable future.

I recently served as the vice-chair of a report entitled *America's Climate Choices* [1] (ACC) issued by the National Research Council of the National Academy of Sciences (NAS) at the request of Congress. That report, the capstone in a 5-report series, brought together more than 90 experts from around the country to think collaboratively about the causes and consequences of climate change and the choices for responding. I believe the ACC reports hold special credibility because they were prepared according to the stringent NAS guidelines for balance, objectivity, and peer review, and because they were developed by volunteer experts, including top climate, social, and economic scientists, as well as leaders from the private sector, and former office holders at the federal and state level.

KEY MESSAGES OF NAS REPORT

The ACC report series summarized what we know about climate change and what kinds of response choices we face as a nation. Some key take home points included:

- Climate change is occurring. The preponderance of scientific evidence suggests that the emissions of greenhouse gases from human activities are the primary cause of global warming over the past 50 years. Climate change poses significant risks for a range of human and natural systems. Greenhouse gas emissions are continuing to increase, which will result in further change and greater risks.

- Some projected future impacts of most concern to the United States include more intense and frequent heat waves, risks to coastal communities from sea level rise, greater drying of the arid Southwest, and increased public health risks. Impacts occurring elsewhere in the world can also deeply affect the United States, given the realities of shared natural resources, linked economic and trade systems, migration of species and disease vectors, and movement of human populations.

- The environmental, economic, and humanitarian risks of climate change and its impacts indicate a pressing need for substantial action to limit the magnitude and rate of climate change and to prepare to adapt to its impacts.

- We can expect always to face some uncertainties about future climate risks, but uncertainty is not a reason for inaction. Indeed uncertainty cuts both ways– while climate change could ultimately prove to be less severe than current best estimates indicate, it could also prove to be more severe. This uncertainty argues for approaching the problem though a process of iterative risk management.

- Current response efforts of local, state, and private sector actors aimed at both mitigation and adaptation are significant, but not likely to yield the degree of progress that could be achieved with the addition of strong federal policies that establish coherent national goals and incentives and that promote strong U.S. engagement in international-level response efforts.

Today, a little less than two years since the report was released, the conclusions of the report remain solid; indeed have been largely strengthened by recent events and scientific findings.

WHAT IS KNOWN ABOUT CHANGES IN THE CLIMATE SYSTEM

John Adams once said, "Facts are stubborn things; and whatever may be our wishes, our inclinations, or the dictates of our passion, they cannot alter the state of facts and evidence." Much of what we know about the climate and the phenomenon commonly referred to as global

warming is the product of more than a hundred years of research, founded on the most basic laws of science such as the First Law of Thermodynamics, grounded by ever-improving observations of the climate system and supported by the paleoclimate record. While climate models play an important role in climate research, it would be incorrect to characterize global warming as conjecture solely based on climate models or simulations.

As context for today's discussions, here are some scientifically documented facts about the climate system:

- Thermometer measurements show that Earth's average surface temperature has risen substantially over the past century, and especially over the last three decades. The first decade of the 21st century was the warmest during the instrumental record, 9 of the 10 warmest years on record occurred since 2001, and the two warmest years on record occurred in 2010 and 2005.[2]
- These data are corroborated by a host of independent observations showing warming in other parts of the Earth system, including the oceans, the lower atmosphere, and ice-covered regions. Further corroboration comes from shifting seasonal patterns, melting glaciers and permafrost, and rising atmospheric absolute humidity.
- How unusual are current temperatures? Two examples: 1. Extreme hot summertime temperatures[3] around the globe now occur more than 10 times more frequently than earlier in the 20th century;[4] and water that had been frozen in the Peruvian Quelccaya Ice Cap for over 6000 years has recently melted.[5]
- The climate in the U.S. has become more variable and extreme. Over the past 50 years we have seen "an increase in prolonged stretches of excessively high temperatures, more heavy downpours, and in some regions more severe drought." [6]
- Carbon dioxide concentrations are higher today than they have been for at least the past 800,000 and we know from isotopic data that most of the increase over the past century has come from burning fossil fuels. A dubious milestone was reached in April 2012, when the first measurement of carbon dioxide concentrations in excess of 400 ppm was recorded at a remote site.[7]
- Greenhouse gases such as carbon dioxide warm the atmosphere and the full impacts of greenhouse gas emissions on the climate do not fully manifest themselves for decades or centuries after they are added to the atmosphere. Some of the carbon dioxide emitted to the atmosphere from the first Model T remains there today and some of the carbon dioxide we will emit into the atmospheric on our trip home today will be warming the atmosphere of our great-great-grand children, and beyond.
- Most of the recent decadal-scale warming can be attributed to fossil fuel burning and other human activities that release carbon dioxide and other heat-trapping greenhouse gases into the atmosphere. Changes in solar radiation and volcanic activity can also influence climate, but observations show that they cannot explain the recent warming trend.

- Human activities have also resulted in an increase in small particles in the atmosphere, which on average tend to have a cooling effect, but this cooling is not strong enough to offset the warming associated with greenhouse gas increases.
- Natural climate variability, for example caused by the El Nino-Southern Oscillation or ENSO, leads to year-to-year and decade-to-decade fluctuations in temperature and other climate variables that can produce significant regional differences and temporarily mask longer-term global climate trends.[8]
- Much has been made by some of the so-called recent "pause" in global warming. It is important to view this phenomenon in the following context: (1) As noted above, the past decade was the warmest on record; (2) There is precedence for warming pauses in the era of human-induced climate change - between 1980 and 2000 there were two periods when global warming halted for a period of years only to resume, and there was the extended warming halt between 1940 and 1970; and (3) The cooler years of the current millennium, which have given rise to the pause, coincided with la Nina phases of ENSO, just as our understanding of the climate system predicts. Indeed Foster and Ramstorf [6] conclude that once ENSO and other short-term influences are accounted for, the global warming signal continues unabated.
- Human-caused climate changes and impacts will continue for many decades and in some cases for many centuries. The precise nature of these impacts cannot be predicted with great certainty. In part because we are not yet able to predict exactly how the climate will respond to increasing levels of greenhouse gases and in part because we are unable to predict how our energy and economy will evolve in the coming decades. However, we do know that the risks for human well-being from climate change are considerable.

In summary, the vast array of climate research, taken together, clearly indicates that climate change is occurring, is very likely caused primarily by the emission of greenhouse gases from human activities, and poses significant risks for a range of human and natural systems. How should we as a nation respond? Borrowing from the earlier mentioned report on America's Climate Choices, some recommendations are presented below.

AN EFFECTIVE NATIONAL RESPONSE

There is, of course, much room for debate about what policies should be implemented to respond to climate change and its impacts, but uncertainty is not a reason for inaction. We, as individuals and as a society, often act in the face of uncertainty. And often we choose to take a conservative path, and rightly so. I, for example, cannot predict if, let alone when, there will be a fire in my house, but I pay for fire insurance. Similarly in the face of uncertain but substantial risks from climate change, a prudent course of action is to develop and implement a risk-based and flexible response to the climate change challenge.

Such a response should have the following elements:

(1) Substantially reduce greenhouse gas emissions. In order to minimize the risks of climate change and its most adverse impacts, the nation will need to reduce greenhouse gas emissions substantially over the coming decades. The exact magnitude and speed of emissions reduction depends on societal judgments about how much risk is acceptable and at what cost. However, given the long lifetime associated with infrastructure for energy production and use (among other factors), the most effective strategy is to begin ramping down emissions as soon as possible.

An optimal response will be one that adopts a portfolio of approaches and policies. Economists[9] find that the most effective way to achieve a national emissions reduction target while minimizing overall costs is with a comprehensive, nationally-uniform price on CO_2 emissions, with a price trajectory sufficient to drive major investments in energy efficiency and low-carbon technologies. This suggests that such pricing mechanisms should be part of the portfolio. Complementary policies to ensure progress in key areas of opportunity where market failures and institutional barriers can limit the effectiveness of a carbon pricing system should also be included.

(2) Begin mobilizing now for adaptation. Prudent risk management involves advanced planning to deal with possible adverse outcomes—known and unknown—by increasing the nation's resilience to both gradual climate changes and abrupt disaster events. Initial steps could include improved early warning and evacuation plans, rezoning to account for the fact that past climatological norms may no longer apply, and shifting incentives to encourage development in less vulnerable regions. Longer term, effective adaptation will require the development of new tools and institutions to manage climate-related risks across a broad range of sectors and spatial scales. Adaptation decisions will be made by state and local governments, the private sector, and society at large, but those efforts will be much more effective with national-level coordination, for instance, to share information and technical resources for evaluating vulnerability and adaptation options.

(3) Invest in science, technology, and information systems. Scientific research and technology development can expand the range, and improve the effectiveness of, options to respond to climate change. Systems for collecting and sharing information, including formal and informal education, can help ensure that climate-related decisions are informed by the best available knowledge and analyses, and can help us evaluate the effectiveness of actions taken. Many actors are involved in such efforts. For instance, technological innovation will depend in large part on private sector efforts, and information, education, and stakeholder engagement systems can be advanced by non-governmental organizations and state/local governments.

(4) Participate in international climate change response efforts. America's climate choices affect and are affected by the choices made throughout the world. U.S. emissions

reductions alone will not be adequate to avert dangerous climate change risks at home, so it is in our country's interest to advance efforts to reduce emissions abroad. A strong effort to reduce our own emissions may enhance our ability to influence other countries to do the same. Similarly the United States can be greatly affected by impacts of climate change occurring elsewhere in the world, so it is in our interest to help enhance the adaptive capacity of other nations, particularly developing countries that lack the needed resources and expertise.

(5) **Coordinate national response efforts.** An effective strategy requires coordination among a wide array of actors. This includes balancing rights and responsibilities among different levels of government (vertical coordination), assuring clear delineation of roles among many different federal agencies and other types of organizations (horizontal coordination), and promoting effective integration among the different components of a comprehensive climate change response strategy (e.g., all of the various types of efforts discussed in the previous recommendations).

ACT SOONER RATHER THAN LATER

The risks of not taking action to deal with climate change seem to far outweigh the risks of taking action:

- The faster that emissions are reduced, the lower the risks, and the less pressure to make steeper and potentially more expensive reductions later.
- Current energy infrastructure investments could "lock in" a commitment to substantial new emissions for decades to come. Enacting relevant policies now will provide crucial guidance for investment decisions.
- Policy changes can potentially be reversed or scaled back if needed, whereas adverse changes in the climate system are likely difficult or impossible to "undo."

STAY FLEXIBLE

Because we cannot predict the exact path the climate will take with a high degree of confidence, we are unable to prescribe a response to climate change today that we know will be optimal for decades to come. And so, we need an iterative risk management approach that systematically and continuously identifies risks and possible response options, advances a portfolio of actions that emphasize risk reduction and are robust across a range of possible futures, and revises responses over time to take advantage of new knowledge, information, and technological capabilities. Flexibility and adaptability are key.

PURSUE "WIN-WIN'S"

There are many "win-win" opportunities, where actions that would help in climate change mitigation or adaptation will also bring other substantial societal benefits, such as increasing energy independence, mitigating air pollution and the resulting health impacts, taking measures to make buildings and population centers more resilient to storms and more energy efficient, and reducing vulnerability to natural weather extremes.

FINAL THOUGHTS

America has choices to make about climate change; choices that we must make in the face of risks that are growing with every new ton of greenhouse gases emitted into the atmosphere. We cannot avoid these choices. I would urge in your deliberations to bear in mind that electing to do nothing is indeed making a climate choice – a choice that our children and their children and their children after them will face increased risks from human-induced climate change.

Thank you for your attention. I will be happy to answer your questions.

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[1] "America's Climate Choices" published by the National Academies Press. Committee Members included: Albert Carnesale (*Chair*), University of California, Los Angeles; William Chameides (*Vice-Chair*), Duke University, VA; Donald F. Boesch, University of Maryland Center for Environmental Science, Cambridge; Marilyn A. Brown, Georgia Institute of Technology; Jonathan Cannon, University of Virginia; Thomas Dietz, Michigan State University; George C. Eads, CRA Charles River Associates, Washington, DC; Robert W. Fri, Resources for the Future, Washington, D.C.; James E. Geringer, Environmental Systems Research Institute, Cheyenne, WY; Dennis L. Hartmann, University of Washington, Seattle; Charles O. Holliday, Jr., DuPont (Ret.), Nashville, TN; Diana M. Liverman, University of Arizona and University of Oxford, UK; Pamela A. Matson, Stanford University, CA; Peter H. Raven, Missouri Botanical Garden, St. Louis; Richard Schmalensee, Massachusetts Institute of Technology; Philip R. Sharp, Resources for the Future, Washington, DC; Peggy M. Shepard, WE ACT for Environmental Justice, New York, NY; Robert H. Socolow, Princeton University, NJ; Susan Solomon, National Oceanic and Atmospheric Administration, Boulder, CO; Bjorn Stigson, World Business Council for Sustainable Development, Geneva, Switzerland; Thomas J. Wilbanks, Oak Ridge National Laboratory, TN; Peter Zandan, Public Strategies, Inc., Austin, TX; Laurie Geller (*Study Director*), National Research Council.

[2] National Climate Data Center, "Global Analysis-Annual 2012, http://www.ncdc.noaa.gov/sotc/global/2012/13

[3] Defined as 3 sigma above the climatological mean; for a normal distribution that would have a probability of 0.27% of occurring.

[4] J. Hansen, et al. Perception of Climate Change, Proc. Natl. Acad. Sci., 1205276109, 2013.

[5] L.G. Thompson, et al. Annually Resolved Ice Core Records of Tropical Climate Variability over the Past ~1800 Years, *SciencExpress*, 1234210, 2013.

[6] National Climate Assessment, U.S. Global Change Research Program, 2012.

[7] National Oceanic and Atmospheric Administration, Carbon dioxide reaches milestone at Arctic sites, http://researchmatters.noaa.gov/news/Pages/arcticCO2.aspx, 2012

[8] G. Foster and S. Rahmstorf, Global temperature evolution, 1979 – 2010, *Environ. Res. Lett.*, 6, 044022, 2011.

[9] W.D. Nordhaus, To Tax or Not to Tax: Alternative Approaches to Slowing Gobal Warming, Review of Environmental Economics and Policy, volume 1, pp. 26–44, doi: 10.1093/reep/rem008, 2007.

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Dr. Bill Chameides has combined more than 30 years in academia as a professor, researcher, teacher, and mentor with a 3-year stint in the NGO world as the chief scientist of the Environmental Defense Fund. He joined Duke as the Dean of the Nicholas School of the Environment in 2007. He is a:

- member of the National Academy of Sciences,
- fellow of the American Geophysical Union,
- recipient of the American Geophysical Union's MacElwane Award,
- named one of the world's most highly cited scientists by the international online research database ISI Highly Cited.com

Bill's research focuses on the atmospheric sciences, elucidating the causes of and remedies for global, regional, and urban environmental change and identifying pathways towards a more sustainable future. His research helped lay the groundwork for our understanding of the chemistry of the lower atmosphere, elucidating pathways for the mitigation of urban and regional photochemical smog, and identifying the impact of regional environmental change on global food production.

Bill has served on numerous national and international committees and task forces and in recognition was named a National Associate of the National Academies for "extraordinary service." In November, 2008, Bill was appointed the Vice Chair of the Committee on America's Climate Choices

http://americasclimatechoices.org/, commissioned by Congress to develop a multi-decadal roadmap for America's response to climate change.

Bill blogs on The Green Grok , The Huffington Post, and the website for Scientific American, ScientificAmerican.com, and is a guest blogger on the Popular Science Magazine's website PopSci.Com.

Research Interests: global, regional, and urban-scale environmental change; causes, impacts, and paths toward sustainable development.

Chairman STEWART. Dr. Chameides, thank you, sir.
And now Dr. Lomborg.

TESTIMONY OF DR. BJORN LOMBORG, PRESIDENT, COPENHAGEN CONSENSUS CENTER

Dr. LOMBORG. Thank you very much. My name is Bjorn Lomborg. I work at the Copenhagen Consensus Center, and adjunct professor at the Copenhagen Business School. We are talking about policy relevant climate issues, so I would like to show a little bit of my testimony, in terms of saying what is actually relevant for the decisions that you will have to make. Yes, as I think all of us agree, global warming is definitely partly, and mostly manmade. It is a long term problem. I have tried to indicate what is the total cost of this, but we are probably talking about 1.4 percent of GDP over the next couple of centuries. Obviously that is an order of magnitude impact. So it indicates it is not the end of the world, as it is sometimes being portrayed, but it is certainly not nothing either, so let us try and get this right.

We also need to recognize that the last 20 years of what we have tried to do has managed to do almost nothing. What you see here is the CO_2 emissions from 1950, and out until 2035 from the International Energy Agency. You see a little bit of crosses around 2010, which was what we promised with Kyoto. We managed virtually nothing. We have spent 20 years, and managed to do virtually nothing. And we need to recognize that the current approach, that focuses very much on saying, it is about wind turbines and solar panels, yes, they are going to help, but not very much. By—right now, about 0.8 percent of all energy comes from modern green agency, and in 2035, with very optimistic scenarios, it is going to be 3.2 percent. So we are talking about a very small part of the solution. If we are going to fix climate change, we will need game changers.

We also need to recognize, as several Members pointed out, cutting CO_2 is not free. There is a strong correlation between how much more economic growth we have and how much more CO_2 you put out. So, again, we have to recognize we are not polluting the atmosphere with CO_2 just simply to annoy the environmentalists. We are doing it simply because it is what powers everything we like. And so, unless we find technologies that allow us to continue economic growth without the CO_2 emissions, I think we are going to find it very hard to get most nations on board to reduce their carbon emissions.

We also need to recognize that, whatever we do, it is only going to have long term impact. No matter what we do, it is really only going to impact the temperature development in the second half of the century. And, as some of the Members also pointed out, we need to get China and the rest of the developing world on board. We can do a lot of good, certainly. I come from the European Union. We feel incredibly virtuous, but we have done virtually nothing. Let me just show you one graph, which I think, in many ways, shows you—this is for Britain, but this is true also for the European Union. If you will look at the blue curve, you see how much Britain has actually cut its carbon emissions, and they are very, very proud of this too. But if you look at the red curve, it in-

cludes how much they also import, minus what they export, of their carbon emissions. And, of course, what they have essentially done, and what a lot of us have done, is we have simply exported a lot of our stuff to China. So we get China to emit all the CO_2 for us, we feel virtuous, but it doesn't actually help the planet.

So, again, we need to find a way that actually works not just to make us feel good, but something that will actually end up doing good. So, fundamentally, if I have to summarize why it hasn't worked so far, well, we have done Kyoto style cuts, which actually cost quite a bit, they do very little good, and we need to recognize that right now, and certainly in the next 10 or 20 years, green energy is not really ready to take over in any major way. We need to recognize that currently we are just spending lots of money doing fairly little good.

This is—I am—I apologize, this is the most complicated graph, but it shows you how much different—of the main countries are paying in implicit CO_2 costs per ton of CO_2. Germany is paying almost $150 per ton. The United States is probably paying a little less than $50 per ton. Compare this to the fact that the best and the largest meta-study of what is the damage cost for an extra ton of CO_2, I estimate it is probably around $5 per ton. So you are—you guys are paying perhaps 10 times too much, Germany is paying perhaps 30 times too much. South Korea, obviously, is just paying through the roof, and there are a lot more expensive solutions. We need to find cheaper ways to tackle global warming.

And that is why I think we need to—if I—in summary, we need to recognize this cannot be about trying to make fossil fuels so expensive nobody wants them. That is never going to work politically, and it is bad economics. Instead, what we do need to do is to focus on making green energy so cheap that everyone eventually will want them. And, of course, that is especially China and India. That is going to happen through innovation. This will take time, and we would all wish this not to be the case, but we have got to face up to the fact that that is the only way we are really going to cut carbon emissions.

We need to recognize we are spending very little on research and development right now. We are spending a lot of money on inefficient cutting of carbon emissions. Why don't we spend more on innovation, and less on cutting carbon emissions? Ultimately, that will end up doing a lot more good.

Let me just—and I don't mean to beat advice or anything, but if you looked at what President Obama said in the—in his State of the Union, he actually proposed an energy security trust. And if you—and it was very sketchy what exactly was going to come out of that, but if—the thrust of that was to say, let us take a little money and spend it on research and development to make green energy cheaper for the future, that way we will cut carbon emissions much cheaper by making it cheap for everyone, also the Chinese and the Indians.

Thank you very much.

[The prepared statement of Mr. Lomborg follows:]

Policy Relevant Climate Issues in Context

Wednesday, April 25, 2013, at 10:00 a.m. in Room 2318 of the Rayburn House Office Building.

The Subcommittee on Environment of the Committee on Science, Space, and Technology

Testimony by Bjorn Lomborg, Copenhagen Consensus Center

Testimony by Bjorn Lomborg for The Subcommittee on Environment of the Committee on Science, Space, and Technology:

Policy Relevant Climate Issues in Context

Wednesday, March 6, 2013, at 10:00 a.m. in Room 2318 of the Rayburn House Office Building.

The most important policy-relevant issues facing decision-makers

I will focus mostly on economic impact and policy, but let me briefly start on the science, which I believe Dr. Judith Curry and Dr. William Chameides will address further.

Is global warming happening? Man-made global warming is a reality and will in the long run have overall, negative impact.

It is important to realize that economic models show that the overall impact of a moderate warming (1-2°C) will be beneficial whereas higher temperatures expected towards the end of the century will have a negative net impact. Thus, as indicated in Figure 1, global warming is a *net benefit* now and will likely stay so till about 2070, after which it will turn into a net cost.

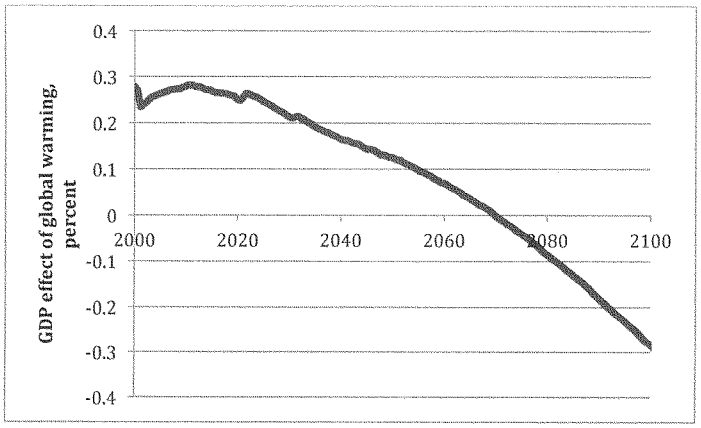


Figure 1 Benefit or cost of global warming.[1]

How important is global warming? To get a sense of the importance of global warming, take a look at the total impact of damage compared to the cumulated consumption using the discount rates from Nordhaus' 2010 DICE model. The total, discounted GDP through the year 2200 (almost the next two centuries) is about $2,212 trillion dollars. The total damage is estimated at about $33 trillion or about 1.5% of the total, global GDP, as indicated in Figure 2. This means that while the global warming impact is *not* zero, it does *not* signify the end of the world, either. It is a problem that needs to be solved.

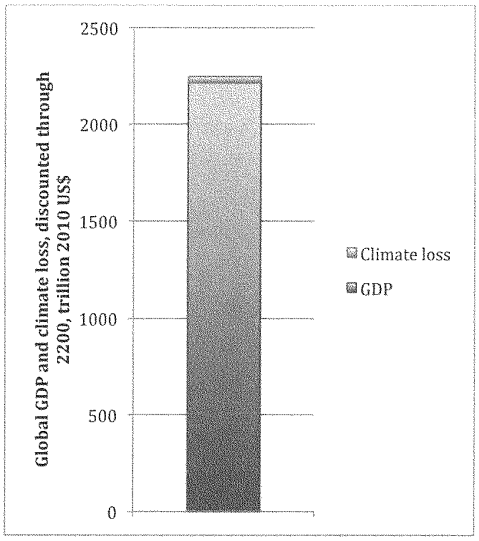


Figure 2 Global, total, discounted GDP through 2200, and climate loss.[2]

How much has the world cut CO2 so far? Very, very little. From Figure 3 it is clear that the world has seen ever increasing CO2 emissions since 1950, and likely will see this continue till 2035. The economic downturn in 2008 led to the reduction in emissions in 2009, but 2010 saw an almost complete rebound. For the Kyoto period of 2008-2012, the global emissions have increased almost 50%. The original reduction suggested by the full Kyoto protocol was 36.6% increase compared to 1990 (the x at 136.6 in 2010). The actual increase came in at 45.4%, and had there been no Kyoto, it would have increased about half a percentage point more at 45.9%. The emissions are likely to continue, here from IEA's 2012 business as usual scenario.

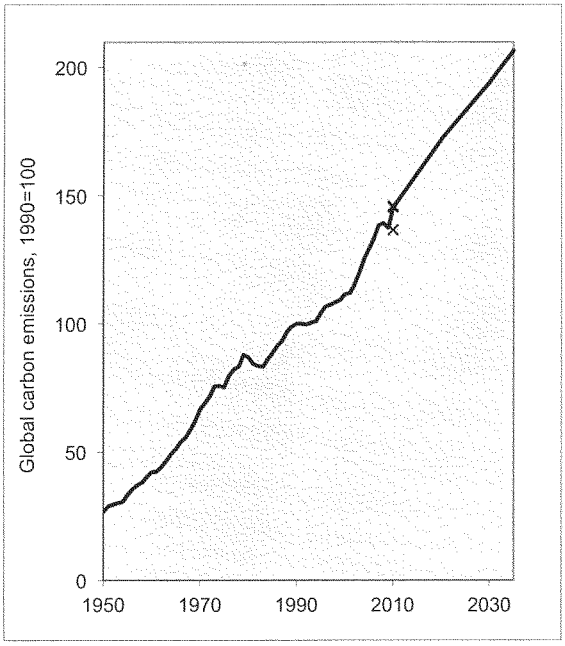


Figure 3 Global CO2 emissions 1950-2010, with estimates for 2020 and 2035 from IEA. Xs indicate original Kyoto reduction promise and actual reduction (of 0.5 percentage point).[3]

We will have lots of renewables by 2035? No. IEA. The world will even in two decades run predominantly on fossil fuels. In 2010 81.2% of all energy comes from fossil fuels. Even with IEA's most optimistic green energy production scenario, 78.5% will still be produced with fossil fuels in 2035. See Figure 4.

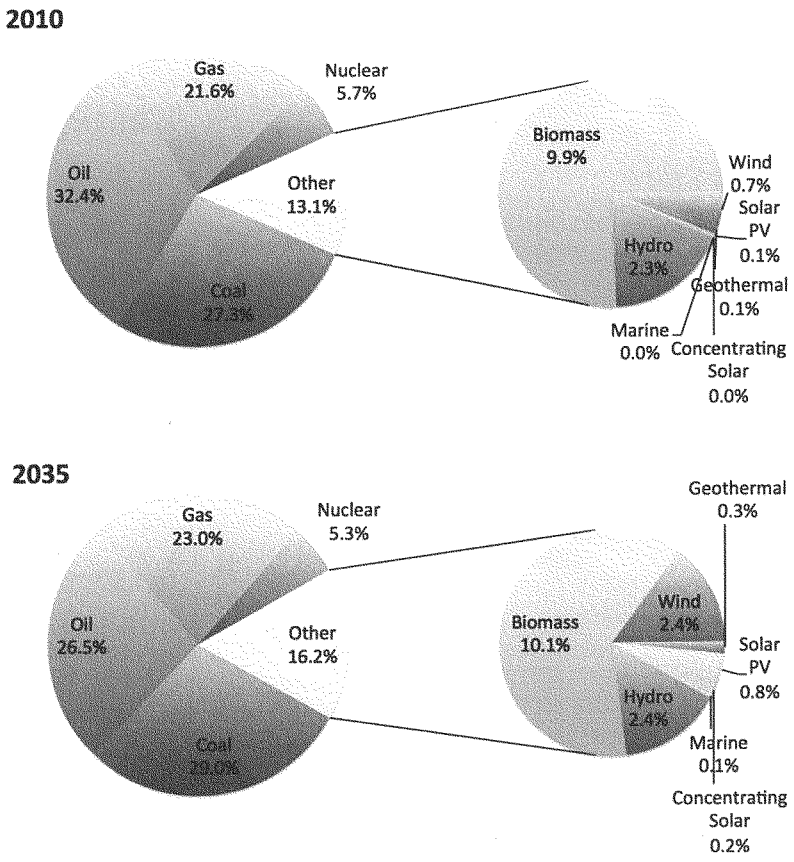


Figure 4 Relative contributions of energy sources, 2010 and 2035, assuming the most green energy production scenario, but keeping the business-as-usual total energy production.[4]

Economic growth and CO2 growth is strongly correlated. In Figure 5 we see how there is a very strong correlation between economic growth and CO2 growth. This underscores the fact that nations don't burn fossil fuel to annoy the environmentalists but because they support economic growth.

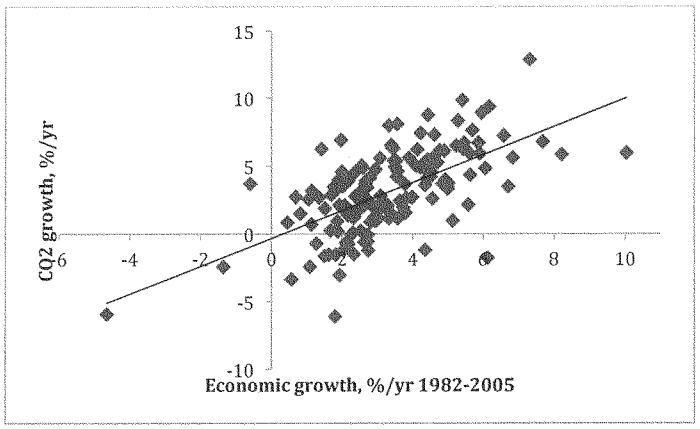


Figure 5 Economic growth per year 1982-2005, compared with CO2 growth per year for the same period. Best fit line added.[5]

What are the uncertainties and certainties of global warming?

There are a large number of uncertainties in global warming science. Dr. Judith Curry and Dr. William Chameides will undoubtedly address these further. However, I think it is perhaps more important to realize that there are a small number of very clear, near-certainties when addressing global warming.

No matter what carbon cuts we make in the next couple of decades, it only makes a difference towards the end of the century. Many people argue that global warming is so urgent that we need to cut carbon emissions *now*. However, the problem is that almost no matter what we do now, it will only have a measurable impact in the second half of this century, as is evident in Figure 6. This matters because many of the cuts that have been proposed are hard to sustain. Thus, what matters is not necessarily to cut a lot now, but to make sure we can cut a lot in the long run.

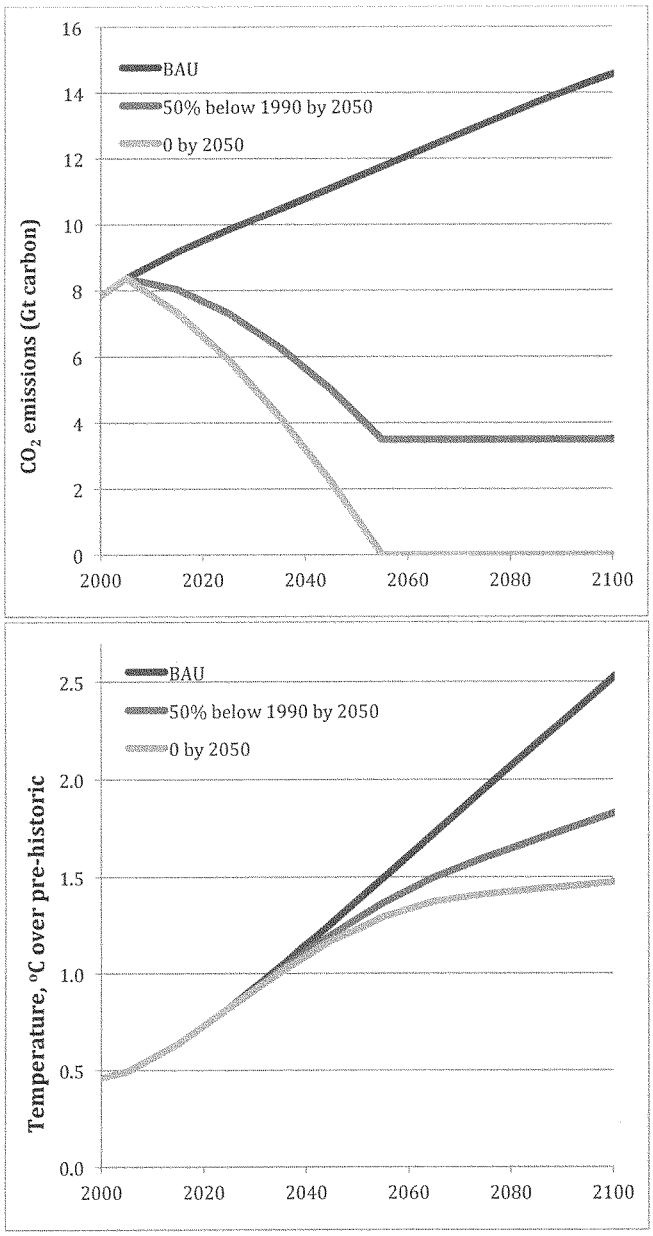


Figure 6 Reduction in CO2 emissions and its consequent reduction in temperature. [6]

What matters in the 21st century is the emissions from the developing world, not the developed world. Whereas the rich world emitted almost all

CO2 in the 20th century, it is now only responsible for 43%, as is evident in Figure 7. Towards the end of the century, that fraction could be down to 23%. Thus, while first world countries can still make climate policies, it will not matter much unless China, India, the rest of Asia, Latin America, Africa and the Middle East is in on it.

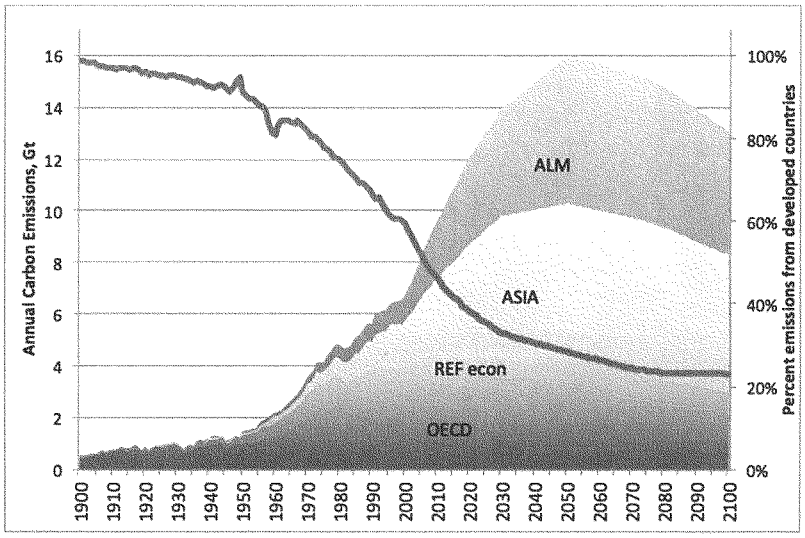


Figure 7 CO2 emissions from fossil fuels and proportion from developed countries, 1900-2100, data and SRES scenario A1B. Regions are OECD, REF economies (Russia, East and Central Europe), ASIA and ALM (Africa, Latin America and Middle East).[7]

Much of the hyped carbon reductions from the West have simply been exported to China. Take the Great Britain's carbon emissions 1990-2010, in Figure 8. Here Great Britain can comfortably claim that it has reduced emissions some 14% over the past 20 years. At the same time, however, imports from other places (typically China) have increased, and when counting both the implicit content of CO2 in these imports (and deducting implicit CO2 emissions in exports), Great Britain has actually *increased* its CO2 emissions over the past 20 years by 18%.

The same holds true for the entire developed world 1990-2008. In Figure 9 we see how the US has increased its territorial (domestic) CO2 emissions, but Europe has reduced its emissions, as has the Former Soviet Union (rest of Annex B). The reductions in the FSU are mainly from the collapse in 1991. But the much vaulted EU reduction is exactly the same as the increased CO2 emissions import from China. Overall, the EU emissions have increased, not as the national accounts seem to indicate, decreased.

This matters because when nations claim to be able to cut CO2, it often simply means that they have exported the CO2 emissions to somewhere else, leaving them feeling better, but obviously with no real environmental benefit.

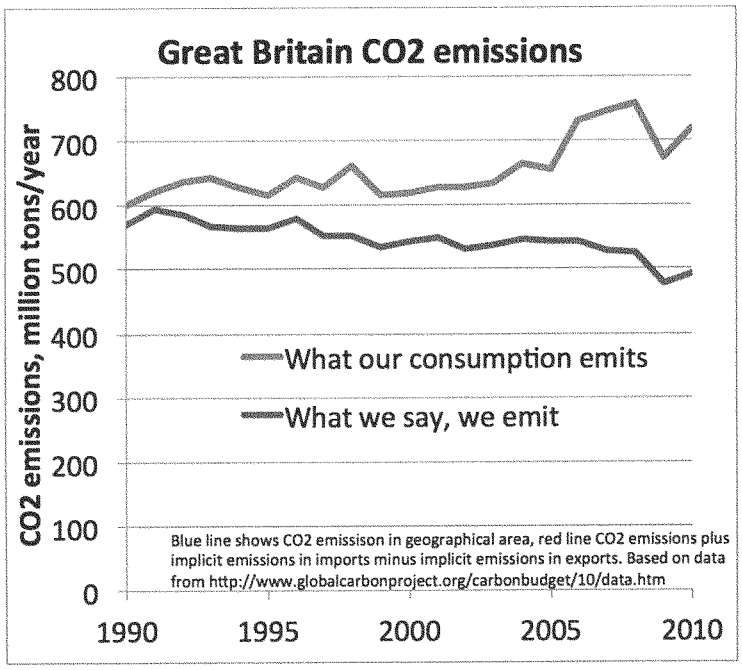


Figure 8 CO2 emissions for Great Britain. Blue line shows the national emissions, the red line shows the emissions including CO2 content in GB import minus CO2 content in GB exports[8]

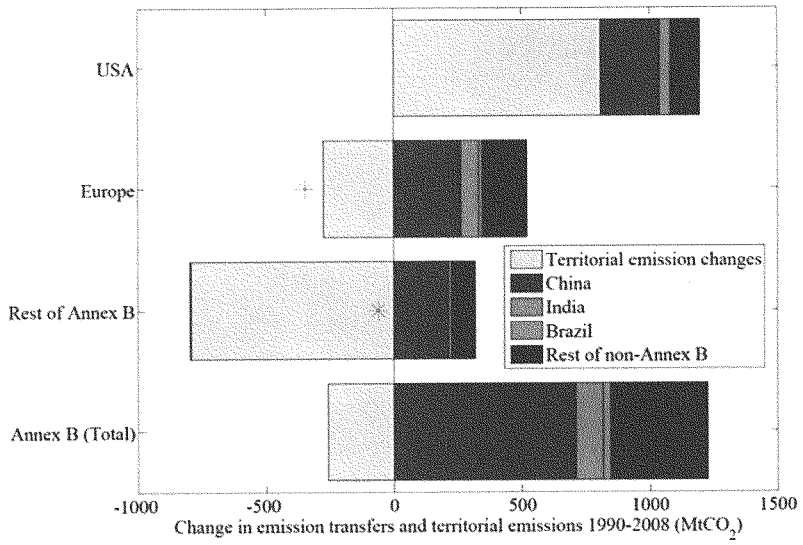


Figure 9 Change in CO2 emissions for developed countries (Annex B) from national (territorial) changes and from imports from China, India and Brazil, 1990-2008.[9]

Failed policies to tackle global warming

Ultimately, the central question of global warming is what to do about it.

The first realization needs to be that the current, old-fashioned approach to tackling global warming has failed, as is evident in Figure 3. The current approach, which has been attempted for almost 20 years since the 1992 Earth Summit in Rio, is to agree on large carbon cuts in the immediate future. Only one real agreement, the Kyoto Protocol, has resulted from 20 years of attempts, with the 2009 Copenhagen meeting turning into a spectacular failure.

The **Kyoto approach is not working** for three reasons. **First**, cutting CO_2 is **costly**. We burn fossil fuels because they power almost everything we like about modern civilization. Cutting emissions in the absence of affordable, effective fossil fuel replacements means costlier power and lower growth rates. The only current, comprehensive global warming policy, the EU 20-20-20, will cost about $250bn/year.[10]

Second, the approach **won't solve the problem**. Even if everyone had implemented Kyoto, temperatures would have dropped by the end of the century by a miniscule 0.004°C (0.007°F). The EU policy will, across the century, cost about $20 trillion, yet will reduce temperatures by just 0.05°C (0.1°F).[11]

Third, **green energy is not ready** to take over from fossil fuels.[12] It is generally much costlier, its deployment does not in general create new jobs (because its higher, subsidized costs destroy jobs in the rest of the economy)[13], and because it typically produces electricity, which is not generated with oil, it doesn't reduce oil dependence[14]. Today, wind supplies 0.7% of global energy and solar about

0.1%, and even with very optimistic assumptions from the International Energy Agency, wind will supply only 2.4% in 2035 and solar 0.8%, as shown in Figure 4.[15]

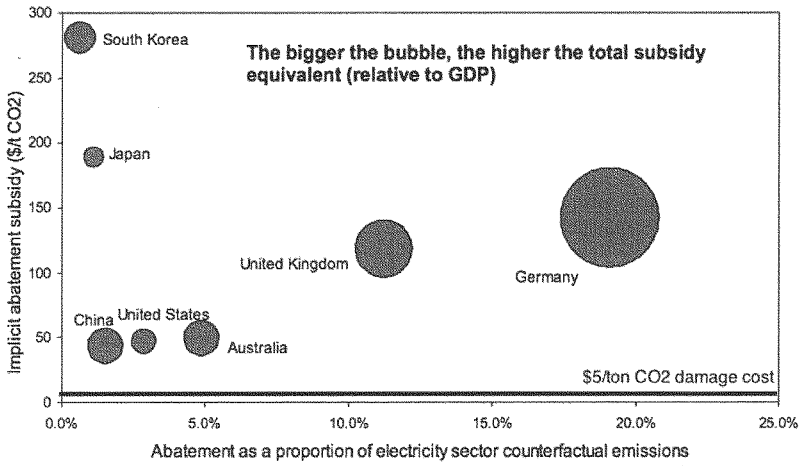


Figure 10 Abatement and implicit CO2 reduction cost for electricity, various nations. $5/ton CO2 damage insert for referece. In AUS$, which is almost equivalent to US$.[16]

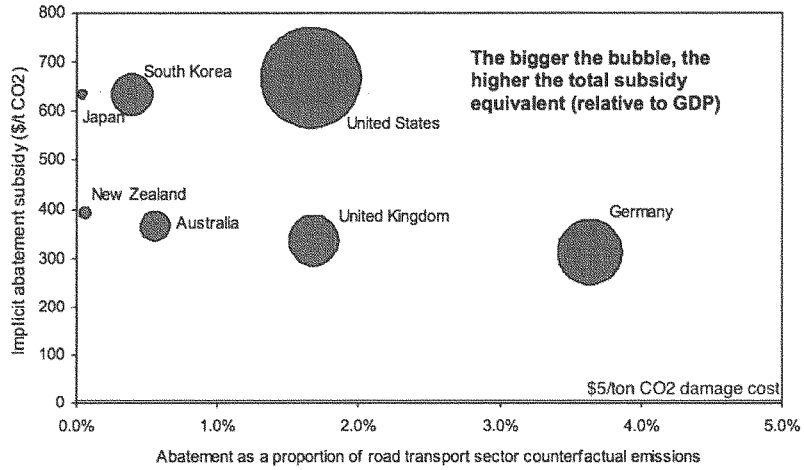


Figure 11 Abatement and implicit CO2 reduction cost for biofuels, various nations. $5/ton CO2 damage insert for referece. In AUS$, which is almost equivalent to US$.[17]

Because there is no good, cheap green energy, the almost universal political choices have been expensive policies that do very little. In Figure 10 we see how all major nations have managed to enact policies for electricity that cost a lot, yet do very little (Germany is leading the pack and still only reducing emissions from the power sector of 19% or 7% of the economy).

The cost per ton of CO2 avoided is universally far above the most likely $5/ton CO2 damage, with China at the cheapest at 8 times the damage of at about $40, and South Korea at a phenomenal $280/ton CO2, 56 times higher than the damage cost. Germany pays each year about 0.3% of its GDP in electricity subsidies.

On biofuels, the excess cost is even more pronounced, and yet the emission reductions even smaller, as can be seen in Figure 11. Germany is paying 62 times too much or $310/ton CO2, reducing just 0.6% of its total emissions at a cost of $1.7bn. The US is paying a phenomenal 133 times too much, at $666/ton CO2, costing $17.5bn/year and reducing just 0.5% of its total emissions.

Yet, the cost is not just in economic terms. There is also increasing dissatisfaction with high energy costs in countries like the UK and Germany. In Germany the cost of electricity has risen 61% in real terms since 2000, as is evident in Figure 12. A fourth of all consumer energy costs are now direct subsidies to renewables. In Rumania, the government just fell because of discontent with high energy costs.

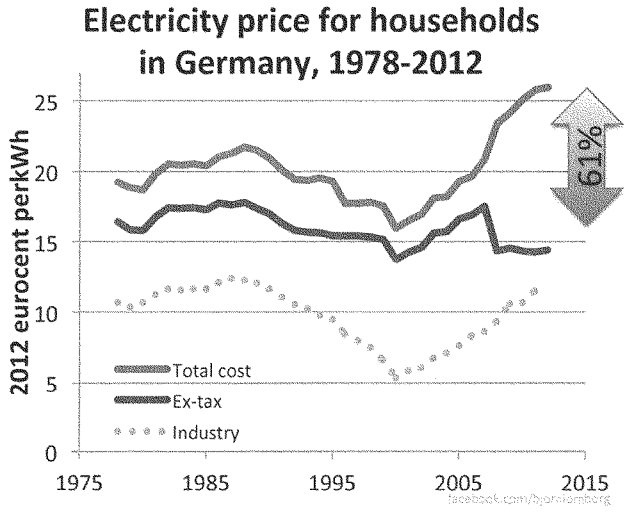


Figure 12 Electricity price for households in Germany, 1978-2012.[18]

Another proposed solution is a **carbon tax** (or an equivalent cap-and-trade). The argument is typically based on the assumption that it would be a significant step toward solving global warming. This is incorrect. If the tax were set high enough to significantly curtail emissions, it would also curb economic growth because of renewable much higher costs. This would be economically inefficient and probably politically impossible to introduce because of the (economic) damage it would cause.

If the tax were set at the economically efficient level, it would not dramatically reduce emissions. Economists agree that a negative externality like CO2 should be taxed at the level of its damage (which is about $5/ton[19] or ¢4/gallon or about €0.01/liter gas), but at this level a tax would make **very little difference** to emissions. If the entire world taxed all emissions at this level, global reductions would only be less than 10 percent.[20] If just one country or region adopted the tax, the effect would be unnoticeable.

A better policy approach to tackling global warming

It is important to realize that the old-fashioned policies have failed. Current green technologies just won't make it[21]. The only way to move towards a long-term reduction in emissions is if green energy becomes much cheaper. If green energy was cheaper than fossil fuels, everyone would switch.

This requires breakthroughs in the current green technologies, which means focusing much more on innovating smarter, cheaper, more effective green energy.

Of course, pursuing an approach of R&D holds no guarantees—we might spend dramatic amounts on R&D and still come up empty in 40 years — but it has much higher likelihood of succeeding than our twenty-year futile attempts to cut carbon so far.

This was the recommendation of the Copenhagen Consensus on Climate, where a panel of economists including three Nobel laureates found that **the best long-term strategy** is to dramatically increase investment in green R&D.[22] They suggested to 10-fold increase the current investment of $10bn to $100bn/year globally. This would be 0.2% of global GDP, and would entail a commitment of about $40bn from the US.

This approach would be significantly cheaper than the current policies (like the EU 20-20) and 500 times more effective. It is also much more likely to be acceptable to the developing countries.

The **metaphor** here is the **computer** in the 1950s. We did not obtain better computers by mass-producing them to get cheaper vacuum tubes. We did not provide heavy subsidies so that every Westerner could have one in their home in 1960. Nor did we tax alternatives like typewriters. The breakthroughs were achieved by a dramatic ramping up of R&D, leading to multiple innovations, which enabled companies like IBM and Apple to eventually produce computers that consumers wanted to buy.

This is what the US has done with fracking. The US has spent about $10bn in subsidies over the past three decades to get fracking innovation, which has opened up large new resources of previously inaccessible shale gas. Despite some legitimate concerns about safety, it is hard to overstate the overwhelming benefits. Fracking has caused gas prices to drop dramatically and changed the US electricity generation from 50% coal and 20% gas to now 30% coal and 35% gas.

This means that the US has reduced its annual CO2 emissions by 400-500Mt. This is about twice the *total* reduction over the past twenty years of the Kyoto Protocol from the rest of the world, including the European Union.

Estimates suggest that the cost of achieving a further 330 Mt CO_2 reduction in the EU would be $250 billion per year using carbon taxes.[23] Yet, the fracking bonanza in the US not only delivers much more than that reduction for free, it also creates long-term, social benefits through lower energy costs.[24] The total benefit to US consumers in terms of lower gas prices is about $100bn.

Table 1 Two policy options with CO2 reductions and costs or benefits.

	CO2 cut/year	Price/year
EU (EU 20-20)	320 Mt	Costs $250bn
US (fracking)	400-500 Mt	Pays $100bn

Summary

How should we tackle global warming?

Don't continue with the old-fashioned, failed policy of the past twenty years. When green energy isn't ready, we're likely to spend vast sums of money on cutting CO2 only marginally.

Instead, we should **focus on investing dramatically more in R&D of green energy**. This will likely bring about green technologies over the next 20-40 years that will be cheaper than fossil fuels, which will mean everyone will adopt them.

In short, **the solution is not to make fossil fuels so expensive that nobody wants them – because that will never work – but to make green energy so cheap that everyone wants them.**

---

[1] Figure 4.1 in Gary W. Yohe, Richard S.J. Tol,, Richard G. Richels, Geoffrey J. Blanford 2009: The Challenge of Global Warming, in Lomborg, B 2009: *Global Crises, Global Solutions*, 2nd edition, Cambridge University Press. http://www.copenhagenconsensus.com/Files/Filer/CC08/Papers/0%20Challenge%20Papers/CP_GlobalWarmingCC08vol2.pdf

[2] Calculated from Nordhaus DICE model 2010, http://nordhaus.econ.yale.edu/RICEmodels.htm

[3] http://cdiac.ornl.gov/ftp/ndp030/global.1751_2009.ems, IEA 2012: World Energy Outlook 2012, http://www.worldenergyoutlook.org/, Kyoto impact estimated from Bohringer, C., & Vogt, C. (2003). Economic and environmental impacts of the Kyoto Protocol. *Canadian Journal of Economics-Revue Canadienne d'Economique*, 36(2), 475–94.

[4] From IEA 2012: World Energy Outlook 2012, http://www.worldenergyoutlook.org/, using New Policy Scenario green energy, but total energy production from Current Policies.

[5] Data from Worldbank Global Development Indicators, http://databank.worldbank.org/data/views/variableSelection/selectvariables.aspx?source=world-development-indicators.

[6] Nordhaus DICE model, 2001.

[7] Data from 1900-2008: http://cdiac.ornl.gov/CO2_Emission/timeseries/regional, Spliced with UN SRES data, AIM A1B scenario. http://sedac.ciesin.columbia.edu/ddc/sres/

[8] http://www.globalcarbonproject.org, downloaded Sept 2012 from http://www.globalcarbonproject.org/carbonbudget/10/data.htm.
[9] p4, Peters, GP 2011: " Growth in emission transfers via international trade from 1990 to 2008" doi: 10.1073/pnas.1006388108, PNAS April 25, 2011 201006388
[10] Richard S. J. Tol (2010) *The Costs and Benefits of EU Climate Policy for 2020*, Copenhagen Consensus Center.
[11] Tol (2010).
[12] Isabel Galiana and Christopher Green (2010) *Technology-Led Climate Policy*, in Smart Solutions to Climate Change; Comparing Costs and Benefits, Cambridge University Press.
[13] Gürcan Gülen (2011) *Defining, Measuring and Predicting Green Jobs*, Copenhagen Consensus Center.
[14] Research by climate economist Böhringer even shows that, fully implemented, the EU 20-20-20 plan does not boost energy security. See: Christoph Böhringer and Andreas Keller (2011) *Energy Security: An Impact Assessment of the EU Climate and Energy Package*, Copenhagen Consensus Center.
[15] International Energy Agency (2010) *World Energy Outlook 2000*, IEA/OECD.
[16] Pxxxvii, Australian Government Productivity Commission 2011: Carbon Emission Policies in Key Economies, http://www.pc.gov.au/projects/study/carbon-prices/report
[17] Pxxxix, Australian Government Productivity Commission 2011: Carbon Emission Policies in Key Economies, http://www.pc.gov.au/projects/study/carbon-prices/report
[18] Data from OECD (prices http://bit.ly/10IXX5I, with 2012 estimated from first two quarters from IEA, and adjusted with German Consumer Price Index (MEI), http://bit.ly/UkWaj7)
[19] Richard S. J. Tol (2011). The Social Cost of Carbon, Annu. Rev. Resour. Econ. 2011. 3:419–43, doi: 10.1146/annurev-resource-083110-120028.
[20] Estimate from Lomborg 2007: Cool It, based on Nordhaus economic models.
[21] For a sobering examination of the scale of the technological challenge, see: Isabel Galiana, Christopher Green (2009) *A Technology-led Climate Policy*, in Advice for Policymakers, Copenhagen Consensus Center.
http://fixtheclimate.com/fileadmin/templates/page/scripts/downloadpdf.php?file=/uploads/tx_templavoila/COP15_Policy_Advice.pdf
[22] Other influential research papers arguing for this approach include:
Prins, Gwyn and Galiana, Isabel and Green, Christopher and Grundmann, Reiner and Korhola, Atte and Laird, Frank and Nordhaus, Ted and Pielke Jnr, Roger and Rayner, Steve and Sarewitz, Daniel and Shellenberger, Michael and Stehr, Nico and Tezuko, Hiroyuki (2010) *The Hartwell Paper: a new direction for climate policy after the crash of 2009*. Institute for Science, Innovation & Society, University of Oxford; LSE Mackinder Programme, London School of Economics and Political Science; and also
Steven F. Hayward, Mark Muro, Ted Nordhaus and Michael Shellenberger (2010) *Post-Partisan Power: How a limited and direct approach to energy innovation can deliver clean, cheap energy, economic productivity and national prosperity*. American Enterprise Institute, Brookings Institution, Breakthrough Institute.
[23] The EU needs to reduce 20% below 1990 by 2020, or 334Mt reduction from 2011; the cost is estimated from five models here:
http://copenhagenconsensus.com/Admin/Public/DWSDownload.aspx?File=%2fFiles%2fFiler%2fArticles+2010%2fcccTolPaper.pdf.
[24] http://rff.org/RFF/Documents/RFF-IB-12-05.pdf

Policy Relevant Climate Issues in Context

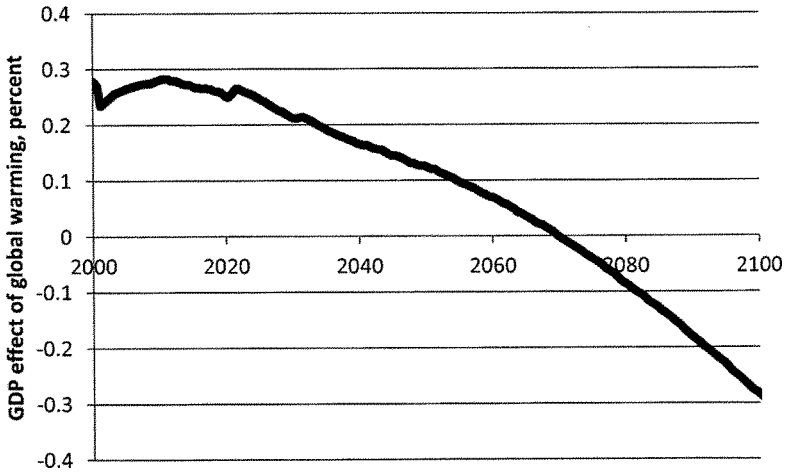
How to tackle global warming – and how not to

Bjørn Lomborg

www.lomborg.com

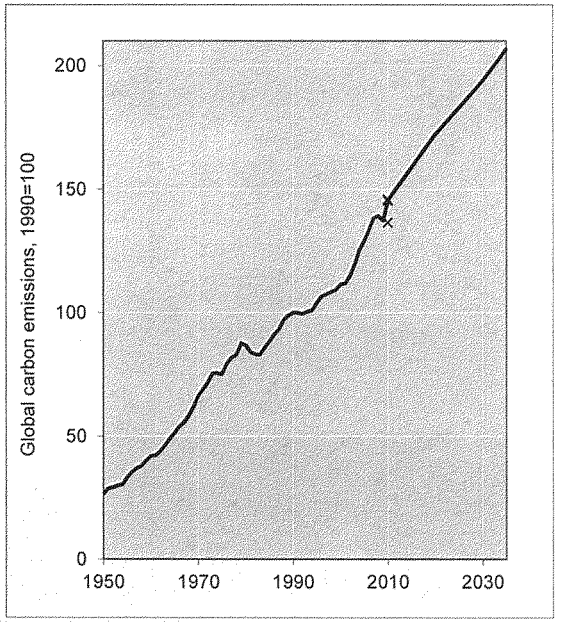
Global warming

- Manmade
- Long-term problem
- Global warming
  - 1.4% of GDP till 2200



We have done almost nothing

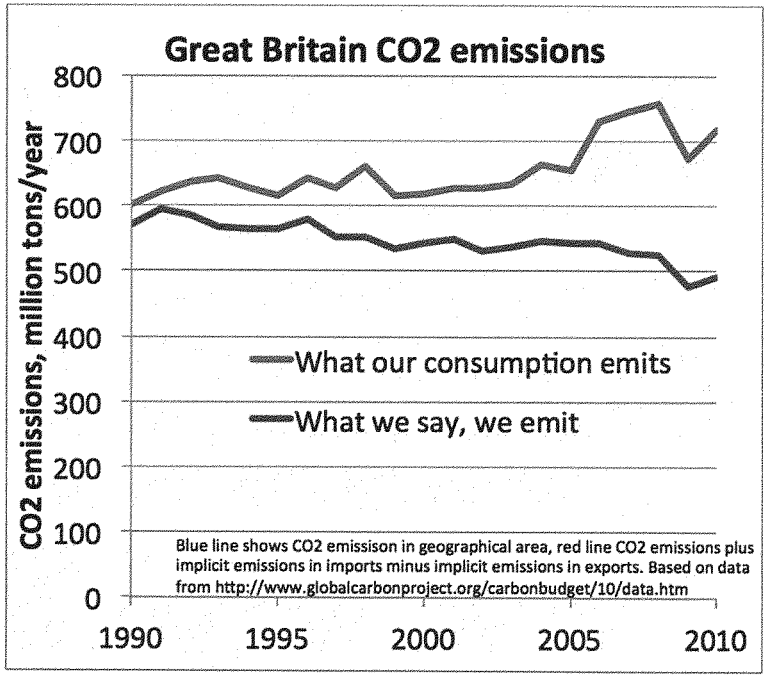
- Kyoto
  - 0.5% reduction
- And green energy won't save us
  - Now
    - 0.8% modern green energy
  - 2035
    - 3.2% modern green energy



CO2 and GDP closely correlated

No matter what we do

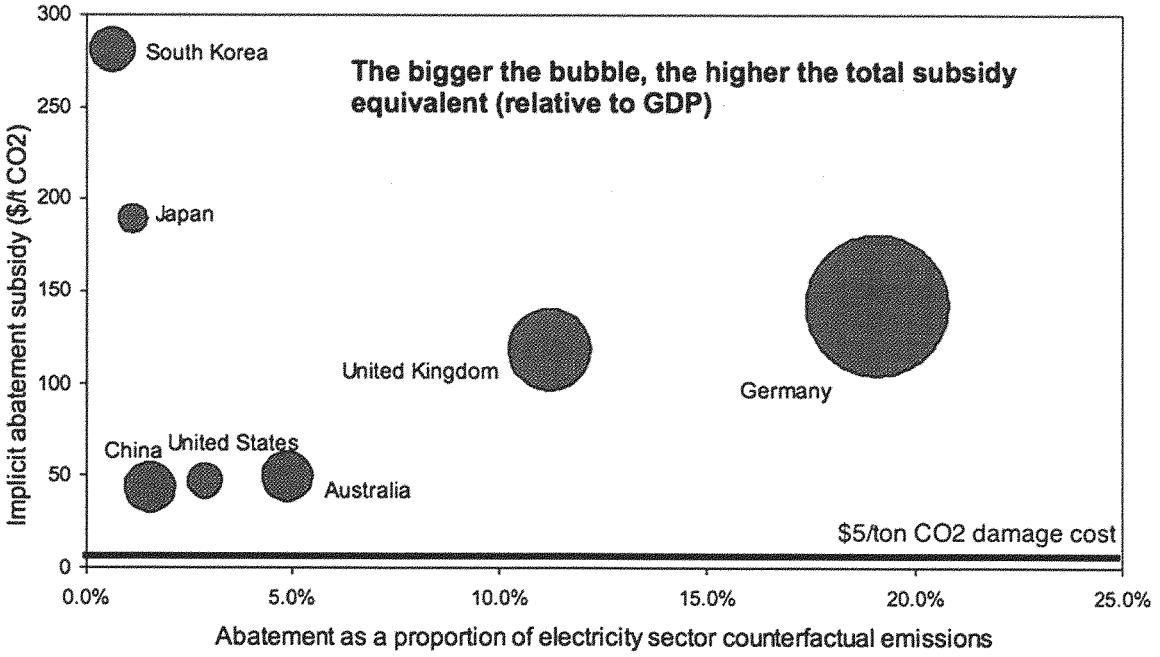
- It will only matter in the second half of this century
- It only matters if we get China and the developing world on-board



Why hasn't it worked so far?

- Kyoto style cuts
  - Cost lots
  - Does little
  - Green energy not ready

That's why we pay too much for green energy



The solution

- Don't try to make fossil fuels so expensive nobody wants them
  - Infeasible politics
  - Bad economics
- Make green energy so cheap everyone wants them
  - Through innovation
    - This will take two to four decades
  - Obama's Energy Security Trust?
  - The computer analogy

Bjørn Lomborg

get the facts straight

search

Biography

Danish biography (http://lomborg.com/about/danish_biography)

Pictures (http://lomborg.com/about/pictures)

Honours (http://lomborg.com/about/honours)

Dr. Bjorn Lomborg researches the smartest ways to improve the environment and the world. He is one of TIME Magazine's 100 most influential people, one of the 75 most influential people of the 21st century according to Esquire magazine, and the UK Guardian names him one of the 50 people who could save the planet. He is a longtime member of Foreign Policy's Top 100 Global Thinkers.

He is an adjunct professor at Copenhagen Business School and regularly works with many of the world's top economists, including 7 Nobel Laureates. His think tank, the Copenhagen Consensus Center (http://copenhagenconsensus.com/) , was ranked by the University of Pennsylvania as one of the world's "Top 25 Environmental Think Tanks".

Lomborg is a frequent commentator in print and broadcast media, for outlets including the New York Times, Wall Street Journal, the Guardian, CNN, FOX, and the BBC. His monthly column (http://www.project-syndicate.org/contributor/bj-rn-lomborg) is published in 19 languages, in 30+ newspapers with more than 30 million readers globally.

Dr. Bjorn Lomborg is an academic and the author of the best-selling "The Skeptical Environmentalist" and "Cool It". He challenges mainstream concerns about the environment and points out that we need to focus attention on the smartest solutions first. He is an adjunct professor at the Copenhagen Business School, and director of the Copenhagen Consensus Center (www.copenhagenconsensus.com (http://www.copenhagenconsensus.com/)) which brings together many of the world's top economists, including seven Nobel Laureates, to set priorities for the world. The Copenhagen Consensus Center is ranked by the University of Pennsylvania as one of the world's "Top 25 Environmental Think Tanks". The Economist said "Copenhagen Consensus is an outstanding, visionary idea and deserves global coverage."

Lomborg is a frequent participant in public debates on policy issues. His analysis and commentaries have appeared regularly in such prestigious publications as the New York Times, Wall Street Journal, USA Today, Economist, Globe & Mail, The Guardian, The Daily and Sunday Telegraph, The Times, The Australian, the Los Angeles Times and Boston Globe. Lomborg's monthly column appears in around 40 papers in 19 languages, with more than 30 million readers. He is a television commentator on CNN, Fox, MSNBC and the BBC, among others, on shows such as "Newsnight", "20/20", "60 Minutes", "The Late Show with David Letterman", and "Larry King Live". He was featured in the movie "Cool it", by Sundance Award winning director Ondi Timoner.

In 2011 and 2012, Lomborg was named Top 100 Global Thinker by Foreign Policy "for looking more right than ever on the politics of climate change". TIME Magazine ranked Lomborg among the world's 100 most influential people in 2004. In 2008 he was named "one of the 50 people who could save the planet" by the UK Guardian. In 2005 and 2008, Foreign Policy and Prospect Magazine called him "one of the top 100 public intellectuals", and in 2008 Esquire named him "one of the world's 75 most influential people of the 21st century."

Bjorn Lomborg was born January 6, 1965.
M.A. in political science, 1991.
Ph.D. in political science at the Department of Political Science, University of Copenhagen. 1994.
Assistant professor at the Department of Political Science (http://lomborg.com/about/www.ps.au.dk) , University of Aarhus, 1994-1996.
Associate professor at the same place, 1997-2005.
Director of Denmark's national Environmental Assessment Institute (http://www.imv.dk/) , February 2002-July 2004.
Organizer of the Copenhagen Consensus (http://www.copenhagenconsensus.com/Default.aspx?ID=158) prioritizing the best opportunities to the world's big challenges, May 2004.
Adjunct professor at the Copenhagen Business School (http://uk.cbs.dk/) 2005-present.
Director for the Copenhagen Consensus Center (http://www.copenhagenconsensus.com/) 2006-present.

Professional areas of interest:

Simulation of strategies in collective action dilemmas; simulation of party behavior in proportional voting systems; use of surveys in public administration; use of statistics in the environmental arena.

Chairman STEWART. Thank you, to all of you, for being available to us in your questioning today. The Committee rules limit questioning to five minutes, and alternating between Republican and Democratic Members of the Subcommittee. And the Chair now recognizes himself for five minutes to begin questioning.

Again, in a sincere way, thank you for a very intellectual—and I appreciate the tone of your testimony today. I do think the nuts and bolts of this issue are fairly straightforward, and several of you indicated that it is risk management, it is risk analysis. What are the actual risks, what are the actual costs, and what is the most effective way to getting and arriving at a desirable outcome, which all of us want to do? I don't know anyone who doesn't want to arrive at the same outcome on this. Of course, analyzing the risk is where this has become so politicized, I am afraid.

And then I think something that I appreciate with this panel here, once the risk is determined, trying to determine the actual cost to it, and what that means. And as I indicated in my opening statement, this can't be borne by a small percentage of people. The cost of this will be borne by all of us, and in some cases by people who can least afford it. And I am not only talking about those of us here in the United States, but around the world, and people who will be, in a very real way, denied a standard of living that allows them for the minimal standards of power, and, in many cases, the things tangent to that. For example, health care.

And, Dr. Chameides, I appreciated your analogy with the fire insurance. And, of course, all of us understand that, but I wonder if you have a scenario where your house is worth $100,000, but it costs you $200,000 to buy an insurance policy for that, and I won't ask you if that is a good decision, because of course it is not, and I think that is where many of us are wondering, what is the cost of that insurance, then? And you list several suggestions in your testimony of things that we could do to substantially reducing greenhouse gas emissions, which is incredibly expensive, and, frankly, changes our whole economy—mobilizing new—now for adaptation. And I won't read your entire list, but, I mean, have you seen any analysis that would give you a figure for that of economic input in dollars?

Dr. CHAMEIDES. Certainly. There have been many, many that had indicated—I mean, it depends, again, on how rapidly you want to decrease, but most analyses have indicated that the price to our economy for decreasing emissions at a substantial rate over the next decade or two are fairly modest, on the order of about one percent or less of GDP.

I think the important thing to bear in mind is——

Chairman STEWART. Could I just interject?

Dr. CHAMEIDES. Sure.

Chairman STEWART. I mean, to some people one percent may be modest, but it is a meaningful amount of money. We are talking trillions of dollars there. Again—yes?

Dr. CHAMEIDES. Yeah, it is true, but it is one percent, okay? Without making a value judgment. But I think the important thing to bear in mind is—I mean, and, again, we can argue about how rapidly we should cut, and how much we should cut, but we are talking about a process of cutting emissions that will need to occur

over many, many decades. We don't necessarily need to make major cuts now. I think it is important that we get started.

One of the analogies that I would make—sometimes there has been discussion about this or that has virtually no impact on the temperature in 2050. I would like to make the analogy of, you know, at some point at the end of this hearing, I am going to head over to the Metro, and it is going to be—let us say 1,000 steps. And I have got to make that first step, and that first step is really important. But someone could say, don't take that first step. It doesn't get you anywhere. I think we have to recognize that that first step in setting us down the road will be very, very important. And it could be very modest. I think we could decide on that.

Chairman STEWART. Okay. If I could shift gears for just a minute, and I will just allow any on the panel to address this, and that is—it is interesting to me that the—if you take the top 20 primary modeling of this, and yet we are about to drop out of the lowest level of that modeling, with this pausing in temperature rise, and none of them predicted that. And, I mean, is there any idea—might that continue for five years, for ten years, for 20 or 30 years? Do we have any idea? Dr. Curry?

Dr. CURRY. I can address that. There are some hypotheses that this could go out for another 20 years or so. Associated—we have recently seen a shift to the cool phase of the Pacific Decadal Oscillation, which means we will see more La Ninas, which have a cooling effect. And this could keep us in a—basically a flat period for several more decades. So we don't quite know—we are also—people are projecting that the sun will be acting in a direction that is towards cooling, relative to what we saw in the latter half of the 20th century.

So there are signals that we could see cooling for the next few—or steady temperatures for the next few decades.

Chairman STEWART. Okay.

Dr. CHAMEIDES. Take a couple of seconds——

Chairman STEWART. Yes.

Dr. CHAMEIDES. —the time has expired. I think we don't know, and there is a chance that it may continue. And, in fact, there is equal chance, and perhaps less—more of a chance that it will increase again at a rapid rate. I think the important thing to do is—if you look at the graph of model predicted temperatures over—and observe, you will find many instances in the record over the 20th century where the model over-predicted the warming for a period of time, like it is now. And what happens is eventually the atmosphere catches up, and, actually, at some points the model underpredicts the warming. So the fact that we are over-predicting the warming right now is not unprecedented, although it is troubling for many of us, yes.

Chairman STEWART. Okay. Thank you. I will give the time over to the gentlewoman from Oregon.

Ms. BONAMICI. Thank you very much, Mr. Chairman, and thank you, panel, for your testimony.

Dr. Chameides, in your testimony you state that most of the recent decadal scale warming can be attributed to fossil fuel burning and other human activities that release carbon dioxide and other

heat trapping greenhouse gases into the environment. Will you please expand on what the other human activities are?

Dr. CHAMEIDES. Certainly. A good deal of it is biomass burning, deforestation, for example. There are also greenhouse gases that other than carbon dioxide. For example, diesel burning, and other solid fuels that give rise to black carbon, or soot emissions. Methane emissions, some from agriculture, some from landfills and so forth are also quite important, for example. Fertilizers tend to emit nitrous oxide, which is also a very effective greenhouse gas. And then there are fluorocarbons that are used in the chemical industry that also contribute to global warming.

Ms. BONAMICI. Thank you very much. And you also state in your testimony that uncertainty is not a reason for inaction, and suggest taking the risk based and flexible response to the climate change challenge. And I appreciate the analogy, like buying insurance for your house, and the Chairman also talked about that, you know, considering what if the insurance costs more than the house? I think I have to submit that it is easier to replace a house than a planet, if we have the kind of damage that could come from climate change. What are the main risks to humans if we don't decrease our emissions? And are there increased risks if delay action? And, in the same vein, you talked about the greater risks from further climate change. Are the risks different as greenhouse gas emissions increase, or are they the same risks, only amplified?

Dr. CHAMEIDES. I would say that, as far as we know, we have a long list of risks. Some of the impacts that we see potentially happening now, and some that we think will come. And I don't necessarily think that qualitatively that will change, although they might become more severe. And, of course, those risks relate to loss of life and property due to extreme weather, droughts. Sea level rise, of course, is a large one. We are seeing what we believe is a decimation of forests in the west from pine bark beetle infestation, which seems to be in part due to the fact that temperatures are so high, and the climate is so dry, and a variety of other things.

I think what is very, very important to bear in mind, in terms of making a decision about the future and the risks, is that the impact of emissions today won't be fully felt for a number of decades. It is sort of the flip side of what Dr. Lomborg was saying. And so if we say, well, let us delay and see what happens in 20 years, basically not only then have we locked in what is happened in the intervening 20 years, but we have now locked in to a future.

And so the issue of the risks that we face is the fact that what we do today will have a major impact in the future, and do we want to take that chance, or do we want to begin to do something to mitigate that?

Ms. BONAMICI. Thank you. Dr. Lomborg, you talked about investing in—heavily in research and development into green technologies. In times of budget constraints, oftentimes those investments are targeted for cuts, unfortunately. And we are committed, I think, in the United States to investing in renewable technology and renewable energy. So could you talk a little bit about what green technologies you would propose, what are the benefits, other than, of course, for the industry itself, of investing in green technology?

Dr. LOMBORG. Absolutely, and thank you. The important part is to recognize that investing in research and development, investing in smart minds—come up with new idea is much, much cheaper than the support that we give to existing inefficient technologies, like subsidizing solar panels or wind turbines right now, so we could actually make money and invest a lot more in research and development. My point is simply to say, we don't know which technologies—and I think we would all agree we don't know what technology's is going to power the middle of the century. But what we need to do, and what America has been so amazing at doing, is to show the way for the rest of the world, coming up with great innovations.

I love—if you know Craig Venter, the guy who sequenced the human genome, he is working on making a bacteria that will essentially be producing diesel. I don't know if it is possible—it is probably technologically possible, but we also know that it is not economically feasible right now, but imagine if we could do it? And those are the kinds of ideas—there are thousands, literally thousands, of ideas out there. They cost very little to support each one of those, and we really just need one, or a few, of those technologies to come through, and they will then make it possible for everyone else, the Chinese and the Indians, to cut their carbon emissions dramatically.

So I agree with Dr. Chameides. Obviously, if we don't do anything for 20 years, we would just have wasted 20 years. But if we actually make sure that the future will have viable alternatives, we could see a dramatic reduction in CO_2 in just a short while, once we get the economics right.

Ms. BONAMICI. I see my time has expired. I yield back. Thank you, Mr. Chairman.

Chairman STEWART. Thank you.

Chairman Smith.

Chairman SMITH. Thank you, Mr. Chairman. It is probably an indication of the expertise of this panel that almost all my questions have already been answered, but I do want to make a couple comments, and maybe come at some of these issues from another way.

Dr. Lomborg, in your last answer, I think you answered one of my questions, which was—you are not suggesting doing that—you are not suggesting delaying. In fact, just the opposite. It is a very active proposal that will actually, I believe, not only benefit America economically, but will actually lead to a greater reduction in carbon dioxide, or other greenhouse gases, and actually lead to a cleaner environment. And I just have a hard time understanding why that doesn't hold more attraction, rather than plowing ahead with policies that we know is going to hurt American economically, and obviously not produce the results that many of us would like, and we could probably agree upon.

Let me ask something else. The United States, as I mentioned in my opening statement, has reduced carbon dioxide emissions 12 percent of the last seven years. The reset of the world has increased carbon dioxide emissions by 15 percent. That is as good of a record as, I think, any industrialized country in the world has, so we can be grateful for what we have been doing in the United

States. And I don't think we need to keep punishing our citizens economically for doing the right thing. But you mentioned a while ago that we are paying 10 times more than we should for I guess energy, but I wanted to ask you to expand a little bit on that. I know you mentioned Germany 30 times or greater, but why are we paying 10 times too much, and how—what is the answer to not doing that?

Dr. LOMBORG. Thank you very much. Yes, fundamentally we have a split in the climate conversation between feeling good and doing good. The feeling good part is where we put up a solar panel that is not yet effective, or a wind turbine that is not yet effective, but telling ourselves, but we are at least cutting carbon emissions. Which is true, but for every ton we cut, we pay perhaps $50——

Chairman SMITH. I see

Dr. LOMBORG. —when the benefit of that ton is only about $5. Now, again, obviously, you can quibble about the exact numbers, but it indicates that we are paying a large sum of money to do a little good.

And I would like to get back to your point of—on the fracking. Fracking is a technology that we invested in from the, what, late '70s in the United States, and we are only just seeing the benefits now. Essentially the United States probably reduced about eight percent just from fracking. So, to put it very bluntly, with fracking you probably cut about 400 million tons every year of CO_2, and you are getting paid for it. You are actually making—compared to prices before, you are probably making about $125 billion a year for the American——

Chairman SMITH. We ought to be encouraging that, rather than trying to——

Dr. LOMBORG. So my——

Chairman SMITH. —deter it, yeah.

Dr. LOMBORG. The simple point is it is a lot easier to cut carbon emissions——

Chairman SMITH. Okay.

Dr. LOMBORG. —and make people money than it is——

Chairman SMITH. Right.

Dr. LOMBORG. —to tell them, could you please cut carbon emissions, and it will cost them a lot of money. And that is what innovation can do.

Chairman SMITH. Exactly. Thank you, Dr. Lomborg. Let me address my next question to all panelists, and, Dr. Curry, start with you. And this is the connection between extreme weather and climate change.

Last year the Inter-governmental Panel on Climate Change, IPCC, found that there is a high agreement that long term trends in weather disasters "have not been attributed to climate change. Droughts have become less frequent, less intense, were shorter in regions like central North America, and the absence of extreme weather trends caused by climate change is also true for floods, tornadoes, and tropical storms." Let me just ask you all if you agree with that conclusion. That was a small part of a larger report by the Panel on Climate Change. Dr. Curry?

Dr. CURRY. I do agree with that statement. The extreme events have been—seemed very extreme the last decade, and they were

certainly more extreme than we saw in the 1980s. But if you go back to the 1950s, and if you go back to the 1930s, you saw similar patterns. You know, droughts in the southwest, elevated hurricane activity, et cetera.

Chairman SMITH. Thank you. Dr. Chameides, do you agree with the IPCC?

Dr. CHAMEIDES. Without saying I agree or disagree, let me just quote to you something that comes from our own U.S. National Climate Assessment. This just——

Chairman SMITH. Is it possible you might tell me whether you agree or disagree?

Dr. CHAMEIDES. I have to see the statement in more detail. It is not—I am not—I just don't know. I can't comment on it.

Chairman SMITH. Okay.

Dr. CHAMEIDES. Well, what it says is that over the past 50 years, for the United States, we have seen an increase in prolonged stretches of excessively high temperatures, more heavy downpours, and, in some regions, more severe drought.

Chairman SMITH. Right.

Dr. CHAMEIDES. So there are some aspects that we are seeing changes.

Chairman SMITH. Yeah.

Dr. CHAMEIDES. This is the U.S.——

Chairman SMITH. I think the point the report is making is to—if you look at this over a number of years, and sort of put it in context that we are seeing that extreme weather occurs many decades ago, and is going to continue to occur, and there is not necessarily any correlation between that and, say, carbon dioxide emissions.

But, Dr. Lomborg, do you have an opinion on that?

Dr. LOMBORG. I think the fundamental point is that there are some things that are actually getting more extreme, but there is also a lot of hype, I would agree. But I think the real point is to recognize trying to regulate extreme weather through carbon cuts is an extremely inefficient way to do it, certainly in the next half century. Now, I think we all agree that eventually we need to fix this, but I would——

Chairman SMITH. Um-hum.

Dr. LOMBORG. —surmise that, to the extent that you worry about people being hit by hurricanes, people being hit by heat waves, there are much more direct, and much cheaper, and much more effective ways to help them in the short and medium, and even rather long term.

Chairman SMITH. And I agree with you. I think technology developments need to come first, and that will yield a better result, and a more cost efficient result as well.

Thank you all for your comments. Thank you, Mr. Chairman.

Chairman STEWART. Thank you, Chairman Smith.

I now turn the time over to colleague from Maryland, Ms. Edwards.

Ms. EDWARDS. Thank you, Mr. Chairman, and Ranking Member Bonamici.

I had hoped that, in today's hearing, we would be able to identify the remaining uncertainties about climate science, and understand our ability to mitigate them, and to inform policy decisions that

protect the public and our economy, and I am not totally sure I have heard that quite yet. And, in fact, it has been quite disturbing, because what I hear from our witnesses is that they agree that climate change is happening, that the globe is warming. They agree that it is some combination of natural occurrence and human activity. And, in fact, all of you are members of various scientific and other societies who conclude that a vast majority what is happening right now is caused by human activity.

And yet, here we are, with one of our witnesses saying, well, you know, let us just wait and invest down the line to get cheaper technology, green technology, that helps us mitigate some of our concerns, and that is really disturbing to me.

Dr. Chameides, in your testimony, you say that greenhouse gases that we emit now are going to linger in the atmosphere for generations, impacting our great-grandchildren, just as we are experiencing the impacts of fossil fuels burned over the last century. And so, considering the position that some are taking, that action now to address climate change is way too costly, and your point about the lingering consequences, isn't the cost of inaction now great, or greater, than the cost of action?

Dr. CHAMEIDES. Thank you. I—my testimony indicates that it is my strong opinion that a prudent course of action would begin to act now. I don't think we can afford to wait. As I said, I think that the issues of how fast, and at what cost, are issues that we should discuss as a society. But I think it is imprudent to decide that we will simply wait and see what happens.

One of the things I said in my testimony with regard to carbon dioxide that I think is useful to bear in mind as a measure, some of the carbon dioxide that we emitted, we emitted, in the first Model T car is in the atmosphere today. And some of the carbon dioxide that we are going to emit when we drive home or whatever tonight is going to be in the atmosphere of our great-great-grandchildren. So there is a decision we have to make about how much of that legacy do we want to leave for our future generations? And every day that we delay means more of our legacy will be that carbon dioxide.

Ms. EDWARDS. Thank you. One of the challenges we have—and, Dr. Lomborg, I agree that we need to make investments in green technology. In fact, I think many of the Members on my side of the aisle have voted repeatedly to make those investments in green technology, and in enhancing research and development activities, and we have been stopped in our tracks over and over again by folks who say, no, we don't want to think about that at all, we don't want to make those kind of investments, when we know that that would be good for the future at the same time that we are trying to reduce CO_2 emissions.

But I am interested in your testimony because you say—and it sounds that our Chairman kind of agreed with the investments in green technology over time, but you are calling for $40 billion of investment from the United States Government in green technology. And I am going to tell you, you go lobby that side of the aisle and see if you can find $40 billion for that kind of investment, because I rather doubt that that can happen, and especially in this constrained environment. And so wouldn't you agree that there has

to be some sort of balance that says we have to both reduce our current emissions—the United States has to take a lead on doing that, try to encourage as much as possible China and India. We know what those contributions are, but we have a little bit of skin in that game, and we have to invest in green technology. But to think that we are going to somehow come up with a magic $40 billion to do that, I think, is—well, it is foolhardy.

Dr. LOMBORG. And thank you very much for those comments. My point is simply to say that those are the technologies that will power the future. What we have seen right now—and let us just remember the last 20 years. We have been making these kinds of statements, especially in Europe, for a very long time. We want to cut carbon emissions, we have given subsidies to a lot of technologies, and we have managed to cut very, very little. And to the extent that we have, we have just exported a lot of our emissions to China.

So my concern is really that, by continuing to say, let us cut carbon emissions, we actually just end up doing very little for a decade or two. I would hate to see that happen, whereas, if we invest in research and development, we could actually get possibly everybody on board. Just to give you a sense of order and magnitude, you are right now spending about $17 billion on biofuel subsidies. That would probably be a good thing to cut. I am sure I am going to offend somebody here. You are certainly also—I would like to just look into those numbers, I can't quite remember them, but you are at least spending $20 billion on subsidies to solar panels. If you add that up, you would have $37 billion I——

Ms. EDWARDS. Well, we need to cut—see, my time is expired, but we must cut CO_2 emissions. That is part of our responsibility. It is the responsibility to challenge our international partners to do that, and to make the investments in green technology and research and development that I would agree that we should.

And my time is expired. Thank you.

Chairman STEWART. Thank you, Ms. Edwards.

Mr. Neugebauer?

Mr. NEUGEBAUER. Well, thank you, Mr. Chairman, and thank you for holding this important hearing, and thank our panelists for being here.

You know, I am just an old land developer from Lubbock, Texas, and so I am not a scientist, but what I do know a little bit about is markets. And I think, Dr. Lomborg, you mentioned that we ought to shift some of our resources into the research side, and what we have been doing is subsidizing alternatives that we thought would be a part of the solution. And, as you mentioned, some of those numbers are big.

And so if we are going to do a cost benefit analysis of these things, doesn't it distort our ability to determine both the cost and the benefit if the government is distorting the marketplace? And, because many of the alternatives that are being offered out there are not commercially viable. And so what happens to things that aren't commercially viable, if—unless the government determines that it is going to subsidize it, they go away, and so those become temporary solutions. So what is your thoughts for the government to step back? I mean, what we have seen from—particularly from

this administration is that you have gone out and given huge loans, and grants, and subsidies to commercial entities, but it turned out that the government thought that was a great idea, the customers didn't agree with that.

So is your—is it your testimony that we should basically get the government out of the subsidy business?

Dr. LOMBORG. No, it is that we should be much smarter about how we make the argument. Let us remember, if global warming is a problem, and I am arguing that, with the best meta-studies, a ton of CO_2 emitted about now causes about $5 of aggregate damage, we need to somehow reflect that. What we need to recognize is that right now we are possibly subsidizing green energy sources to the tune of $50 per ton of CO_2 avoided, so we are paying too much to avoid too little damage.

But that doesn't alleviate us from actually having to do something to avoid those tons that the United States is responsible for. But, of course, we would also like to see all the tongs that the Chinese are responsible for, and the Indians are responsible for. And, as the Chairman rightly mentioned, I think the Chinese and Indians are more concerned about just getting their kids an education, and food on their table, and a lot of other issues. So it lies to our responsibility to make sure that we invest smartly so that we can avoid that extra damage down the line.

If you invest in research and development—and there will be an under investment in research and development in the private market, simply because if you—imagine Mitchell, he did the first fracking back in '78. If nobody had supported him, why on earth would he have done it? Because had he found out how to frack spending 30 years, he would have not been able to patent that. He would probably not have been able to recoup all those benefits. There are huge social benefits. That is why we invest in medical sciences, to—for people to come up with great new cures. And, likewise, we should be investing in long term innovation for technology.

So my argument is to say stop subsidizing as much, and start investing a lot more in research and development.

Mr. NEUGEBAUER. Dr. Curry, do you concur with that?

Dr. CURRY. Well, yeah. I didn't hear much that I would disagree with.

Mr. NEUGEBAUER. Okay. And, one of the things that you bring up, and it is a concern I have, is that if the rest of the world—I mean, we almost make it sound like it is—that the United States is the number one contributor to greenhouse gases in the world, and that is, from my reading, is not the case. Is that—anybody disagree with that? So the question is, if the rest of the world isn't going to either have the resources to make these investments, or decides not to buy into it, and what we have seen is many of the other countries have not bought into it, then doesn't that diminish our ability to really have impactful changes, if, in fact, we are affecting the climate? Yeah.

Dr. LOMBORG. Sorry. Just very briefly, if you do a cost benefit analysis, the current approach is probably not a good way to go. But if you invest in research and development, the benefits could be 10, or even more, the amount of dollars that you put in. So it

would both benefit the United States, because you would have better technology for the future, and you would also help the rest of the world. I would surmise that might be a good deal, even just for the United States. But, of course, it would be ideal if we could also get China and India on board.

Chairman STEWART. Thank you again. It looks like our last questioner today is Mr. Weber.

Mr. WEBER. Dr. Lomborg, I think—and I came in late, and didn't get to hear all of you all's testimony, I apologize, so I am—I will go with what I have got. I believe you testified you recommend $40 billion in research from the United States, and my colleague down on the other side of the aisle said, you know, go lobby this side of the aisle. How much luck have you had lobbying China?

Dr. LOMBORG. We asked some of the world's top economists what are the smartest ways to deal with global warming, and what they suggested was we should be spending 0.2 percent——

Mr. WEBER. Are you lobbying China, and Russia——

Dr. LOMBORG. Yes.

Mr. WEBER. —and India?

Dr. LOMBORG. Yes, but it is——

Mr. WEBER. Okay.

Dr. LOMBORG. —also important——

Mr. WEBER. How much money are they investing?

Dr. LOMBORG. Well, they are investing some money, but, honestly, I don't know what——

Mr. WEBER. Somewhere south of 40 billion, I suspect?

Dr. LOMBORG. Yeah. Let us also say I am suggesting it is a percentage of——

Mr. WEBER. Okay.

Dr. LOMBORG. —GDP, so they would be investing a lot less.

Mr. WEBER. And this is a question for all three of you. Are you all aware of the amount of energy required, alternating current, to run an electrical grid, for example, the size of the one in Texas, which is 85 percent of the state? Are you all aware of how much energy is required, and how much of that is alternating current, how much direct current, which would be solar panels, produces for that grid? Dr.—is it Chameides, Chameides? Are you aware of that?

Dr. CHAMEIDES. I don't know the numbers.

Mr. WEBER. How about you, Dr. Curry?

Dr. CURRY. I don't know the numbers, but I am doing research related to wind energy generation——

Mr. WEBER. Okay.

Dr. CURRY. —and——

Mr. WEBER. All right. Well, I own an air conditioning company, and let me tell you, it is a huge amount of power required to power a compressor to enable us to sit here today without the windows open, with the lights on, and also to do things like refrigerate your food. Just minor details.

Our quality of life is sustained by the energy that America produces. The things that make America great are the things that America makes. We have the most stable energy source in the world, and that is not by accident. That is by entrepreneurs getting out and developing their industry, and risking their capital. And I

will get off that soapbox for a minute, and I will ask you all questions.

So—there is advocacy going on that the United States needs to cut their CO_2 emissions, while the rest of the world, admittedly China, Mexico, India, and some of the other countries will not. All that does is puts us at an economic competitive disadvantage, and, in fact, would enable them to perhaps become the world leader in the market economy. Our quality of life would go down. We would export a lot of jobs overseas. Without really knowing that global warming is affecting us, are any of you able to adequately measure the amount of a tree's ability to assimilate CO_2 and carbon dioxide, and to reproduce oxygen? Do we know that? Is that factored into you all's thought process? Do we need to plant more trees? Dr. Curry?

Dr. CURRY. That is certainly a, you know, a good thing. It would have many beneficial impacts on the environment——

Mr. WEBER. Okay.

Dr. CURRY. —but there are ways of natural sequestration of CO_2.

Dr. CHAMEIDES. There are a variety of ways of using land, farm land in particular, and forests, to what we call offset the emissions from the energy grid, and allowing those offsets into a system would greatly reduce the costs.

Mr. WEBER. Okay. And let me—my time is running short here. Dr. Chameides, I think you made the comment that the CO_2 emissions from Model As and Model Ts are in still in the atmosphere, and I am curious how you have been able to identify those, because I can't tell them apart from the '56 Chevy I drove in high school.

Dr. CHAMEIDES. I—they are playing ragtime music. No, I am sorry, I apologize.

Mr. WEBER. That is all right.

Dr. CHAMEIDES. So we—first of all, we know that the extra carbon dioxide in the atmosphere is largely coming from burning of fossil fuels from isotopic data. And from that isotopic data as well, we can estimate fairly well, accurately, how long a carbon dioxide molecule ultimately stays in the atmosphere, in a sense, after it has been emitted. And from those two things we can estimate how much of the carbon dioxide that was emitted, say, in 1920, or '15, or whenever it was——

Mr. WEBER. Okay.

Dr. CHAMEIDES. —is still in the atmosphere today.

Mr. WEBER. Okay. And then, lastly, if we are wrong on global warming, and if global cooling results in the next—does—that become the discussion in 40, or 50, or 75 years, how does the United States recover from losing its market edge in the world, from a policy standpoint? How do we recover from that mistake? Dr. Curry?

Dr. CURRY. Well, this is why I suggest we need to consider a broad range of possible future climate scenarios on time scales, you know, out to 3, 4, 5 decades, versus, you know, this century. What may happen, you know, on the near term decadal time scales may going in a different direction than the longer term change, and I think those are the kinds of scenarios that we need to consider if our policies are going to be robust.

Dr. CHAMEIDES. I guess I—with all due respect, I would question the premise. I think we can intelligently come up with a large port-

folio of options and policy responses, including investments in research and other types of activities that will not substantially change our market position.

With regard to the China and other countries, I think, you know, we need to recognize that it is a double-edged sword. We are in a bit of a bind, because their emissions threaten our well-being. And so it behooves us to not only worry about what we are doing, but to engage with those countries to get them to get—be serious about their emissions. And China is a strange animal, but they have actually built a lot of coal fired power plants, but they have also invested in a lot of renewable energy. I think about 25 percent of their rebuilds——

Mr. WEBER. Okay.

Dr. CHAMEIDES. —is——

Mr. WEBER. And, I am sorry, I am out of time, but, Dr. Lomborg, Mr. Chairman, if I may very quickly? How do we recover?

Dr. LOMBORG. Well, I think your point is well taken that you are not going to see dramatic reductions if it actually starts impacting people's life quality. And I think that is really the argument for why we haven't done anything in the——

Mr. WEBER. Thank you.

Dr. LOMBORG. —last 20 years. So we need to find smarter ways that is actually going to bind everyone together, and it is going to be cheaper.

Mr. WEBER. Thank you. I yield back the time I don't have.

Chairman STEWART. Yes, Mr. Weber. And I misspoke, you are not the last questioner today.

Mr. Rohrabacher?

Mr. ROHRABACHER. Thank you very much. And I did hear your testimony, and I had to run off to the Foreign Affairs Committee to see that we don't borrow money from China, in order to give money to China, because of predictions of global warming.

Now, I can remember at least 10 different occasions in my memory of scientists who have said, case closed. Remember that expression? Case closed, there is global warming. And I remember my colleagues picking up on that, on the other side, case closed. And you still hear that ringing, that—well, this is—what—the change in the climate is due to man-made activity, and this was done in order to suppress debate. Let me just say that I have in 24 years in Congress, and I was a journalist and a writer before that, and spent some time in the White House, I have never heard such an effort go on among academic people to cut off debate on an issue than this one. I have never seen it before.

Let me ask you some specific questions. You have some experts here now. It appears to me that the baseline for deciding how much warming is taking place is around the 1850s. And the baseline that we are talking about, in the 1850s, happens to be at the very tail end of a couple hundred years of what is recognized cooling. Have we come back to the point yet that there was a natural thing before that cooling started. Is the temperature of the Earth yet back to what it was before it went through the mini-Ice Age? Are we back to that temperature yet before the mini-Ice Age?

Dr. CURRY. Well, there is debate about what the, you know, what the global temperature was during, say, the medieval warm period,

and it is very hard to sample and infer all that. So that is an area of active debate.

Mr. ROHRABACHER. Do we have—anybody else have any suggestions on that?

Dr. CHAMEIDES. A wide number of studies, in a variety of different ways, indicate that the present day temperature is warmer than it has been probably for at least 1,000 years or longer. Let me just give you one——

Mr. ROHRABACHER. Well—but, wait—but we don't know the——

Dr. CHAMEIDES. One——

Mr. ROHRABACHER. One question. We don't know that—even if it is hotter than it was before the decrease in temperature, when we are claiming that this is some abnormal——

Dr. CHAMEIDES. It is higher——

Mr. ROHRABACHER. —change?

Dr. CHAMEIDES. —than—it is higher than temperatures that we have seen for 1,000 years, so it goes——

Mr. ROHRABACHER. Okay.

Dr. CHAMEIDES. Okay.

Mr. ROHRABACHER. All right.

Dr. CHAMEIDES. Let me just give you one simple example——

Mr. ROHRABACHER. Yeah, you said it. The reason why I stopped is to clarify that, because you said it is hard to tell——

Dr. CHAMEIDES. No.

Mr. ROHRABACHER. —but——

Dr. CHAMEIDES. There is——

Mr. ROHRABACHER. Okay.

Dr. CHAMEIDES. These analyses are difficult, but there are many of them. Let me just give you one example that I think well illustrates what we are talking about.

Mr. ROHRABACHER. Um-hum.

Dr. CHAMEIDES. There is a glacier in Peru, it is the—I will—I am going to do a terrible job. I think it is Quelccaya Glacier, that we have been following for rather a long time. Ice that had been in that glacier continuously for 6,000 years has recently melted. So, in other words, that glacier's ice has been sitting there for 6,000 years, through the medieval warm period, all this other stuff——

Mr. ROHRABACHER. Um-hum.

Dr. CHAMEIDES. —and now it is melted. Those kinds of—that kind of information sort of indicates to me, more than sort of for me, anyway, that something unusual is going on.

Mr. ROHRABACHER. Dr. Curry, do you agree with that?

Dr. CURRY. Well, the issue of trying to infer globally what the climate was like, you know, 1,000 years ago is very, very difficult, you know, and so we have regional expressions, such as what was mentioned. But how to infer what was going on globally, you know, the estimates are very indirect, and, again, there——

Mr. ROHRABACHER. Well, especially mankind's—when people are advocating not just that we are in some kind of a warming trend—I don't know anybody that denies that we have gone through warming and cooling trends, but how much of this has anything to do with human activity, and gives an excuse, by government, to control human activity, meaning our lives and our freedom? There is no way to know whether that glacier was melting as a result of

a natural trend, or by the fact that too many people drive cars now, and too much combustion from—too much CO_2. There is no way to know what that—what actually caused that glacier to go back.

Now, let me ask—people have told me that this melting in the Arctic, that we actually had very similar meltings in the Arctic in the 1930s. Is that correct?

Dr. CURRY. Actually, the analogy was in the 1950s we saw a melt back in the western Arctic, the European Arctic, that wasn't quite as big as today. But in terms of, you know, trying to put together this—hemispheric sea ice records prior to the satellite era, prior to——

Mr. ROHRABACHER. Um-hum.

Dr. CURRY. —1979 is challenging. And——

Mr. ROHRABACHER. Yeah.

Dr. CURRY. —there is a lot of Russian data that really needs to be incorporated. And there is an international effort, trying to take the sea ice record back to 1880 in a more robust way.

Mr. ROHRABACHER. Okay. And I would like to know—when you mentioned, Doctor, that we have the warmest nine years on record now in the last nine years, what is on the record mean? Where does that start at the——

Dr. CHAMEIDES. I meant——

Mr. ROHRABACHER. —bottom of——

Dr. CHAMEIDES. —the instrumental record, yes.

Mr. ROHRABACHER. Are we talking about the bottom of the global cooling era there, those hundreds of years where you had that mini-Ice Age? Is that what you are starting there as on the record?

Dr. CHAMEIDES. Yes, but it is the warmest.

Mr. ROHRABACHER. Yeah. So on the record there could mean something, it could mean nothing. Because——

Dr. CHAMEIDES. Well——

Mr. ROHRABACHER. If we are talking about using a baseline that is way below some average, well, then that base—then it is irrelevant.

Dr. CHAMEIDES. Well, your point is well taken, but the other data that we have, this paleo climate data, would indicate that the temperatures we have seen, not necessarily on a decadal time scale, but several decadal time scales, are warmer than we have seen for a long, long time. As I said——

Mr. ROHRABACHER. Long, long time?

Dr. CHAMEIDES. —1,000 years, 2,000 years, something like that.

Mr. ROHRABACHER. Before mankind existed, there were times when more CO_2 was in the air. We had times before mankind existed when it was warmer. And when we had, before mankind, cycles of warming and cooling. Maybe the sun has something to do with it.

Chairman STEWART. And the gentleman's time has expired.

Mr. ROHRABACHER. Thank you.

Chairman STEWART. Thank you.

I would like to thank the witnesses once again for your valuable testimony, and for—the Members for their questions. The Members of the Committee may have additional questions for you, and we will ask you to respond to those in writing, if that is the case. The record will remain open for two weeks for additional comments and

written questions from the Members. Witnesses, once again, with our gratitude, you are excused, and this hearing is now adjourned. Thank you very much.

[Whereupon, at 11:20 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Judith Curry

Hearing Questions for the Record
Requested by Chairman Chris Stewart
Policy Relevant Climate Issues in Context

Responses submitted by Judith Curry

1. According to the primary temperature datasets used by climate scientists, global warming stopped in 1998 and has been flat for about 15 years. How do those that assert "the science is settled" explain this lack of warming?
   a) If the lack of warming is explainable at all, why were all the climate models unable to predict it? Shouldn't the models' inability to predict the absence of warming in the present be a red flag to our confidence in their ability to predict warming in the future?

A recent article in The New Republic interviewed a number of scientists on this topic, who have been involved in the IPCC.
http://www.newrepublic.com/article/113533/global-warming-hiatus-where-did-heat-go#
Various ideas have been put forward: 'natural variability', sequestration of the heat in the deep ocean, the sun, decreasing stratospheric water vapor, increasing aerosols. There is substantial disagreement among these scientists

I absolutely agree that the models' inability to predict the absence of warming in the present should be regarded as a red flag to our confidence in their ability to project warming in the future.

2. Most of the discussion over extreme weather events seems to center on cost. Some have even gone so far as to suggest the financial cost of the disaster is somehow correlated to climate trends. For example, the Federal government (through NOAA) maintains a "Billion Dollar Disaster" database
   a) is there a relationship between the financial damages incurred by an extreme weather event and long term climate trends?
   b) Or would you say that the amount of financial damages instead correlates to other factors, such as where the storm makes landfall, population density, degree to which infrastructure has been hardened, property values, etc.?

The recent IPCC SREX report states:
"Increasing exposure of people and economic assets has been the major cause of the longterm increases in economic losses from weather- and climate-related disasters (high confidence)."

3. Following the hearing, Dr. William Chameides wrote, "in general uncertainties tend to cut both ways – some suggest that the climate disruption will be less than currently predicted and some that it will be worse." Do you agree?

In my testimony, I stated:

Returning to my experiences with decision makers in using weather and seasonal climate forecasts, I would like to remind that uncertainty about the future climate is a two-edged sword. There are two situations to avoid: i) issuing a highly confident statement about the future that turns out to be wrong; and ii) missing the possibility of an extreme, catastrophic outcome.

So while in principle I agree with Chameides, the main point is that in context of the approach that the climate scientists have been using, the uncertainty strongly suggests that the climate disruption will be less than currently predicted.

Responses by Dr. Bjorn Lomborg

Hearing Questions for the Record
The Honorable Chris Stewart

Policy Relevant Climate Issues in Context

Dr. Bjørn Lomborg

Q1. In your testimony you state that the Kyoto approach is not working, and furthermore that cutting CO2 is costly. In fact, you note that the only current comprehensive global warming policy in the EU will cost about $250 billion per year. Who will bear the brunt of these costs? Will the benefits of this policy outweigh the costs? Are they even measurable?

a. Given the extremely high cost and the lack of benefits and marginal reductions in temperature, was there a cost benefit analysis performed when evaluating the merits of this policy?
b. Do you think there is a place for economic cost analyses or cost benefit analyses when evaluating climate mitigation policies?

A1. There has been a number of cost-benefit analyses of the Kyoto Protocol. Most show that it does not stand up – probably the benefits is about 15 cents back on the dollar (http://www.econ.yale.edu/_nordhaus/hompage/Kyoto.pdf). And yes, while economic cost-benefit analysis should not be the only input, it is a very important part of rational decision-making.

Q2. One of the major challenges of the global energy system is access to affordable energy supplies. Over 1.6 billion people, 25% of the world's population, do not have access to electricity. Affordable, secure and reliable electricity supply enables economic development which is a prerequisite for poverty alleviation. Coal plays a central role in supporting global economic development, alleviating poverty and is an essential resource to meeting the world's energy needs. Coal currently supplies 27% of primary energy and 41% of electricity generation, and coal use is expected to rise 50% to 2030, with developing countries responsible for 97% of this increase, primarily to meet electrification rates.

a. How would a climate change mitigation strategy affect those 1.6 billion people, particularly one that denied them the opportunity to access reliable, inexpensive coal-fired electricity?
b. Without cheap affordable power, what will happen to economic development and poverty alleviation efforts?

A2. It is crucial to get electricity to the 1.5bn people who do not currently have access(and modern fuels to the more than 2.3bn, who don't have access). This is both important in

terms of health but also economic development. It is perhaps worth realizing that China lifted 680m people of poverty the last 30 years, but they did not do so through wind or solar, but by massive (and polluting) coal.

Q3. A few years ago you led an effort to prioritize a number of global challenges in order to determine the most cost-effective way to improve the quality of life for people around the world. Recognizing that we have limited resources, you ranked the value of addressing problems such as disease, malnutrition, climate change, health care, sanitation, and water quality. Compared with these challenges, climate change came in last—signaling that spending billions to address it would have the lowest impact for the highest cost.

a. Can you discuss this effort in a bit more detail, and explain why you concluded that climate change was last on the list of global challenges to address?

A3. The Copenhagen Consensus tries with some of the world's top economists to identify the best solutions to the world's top problems. The best introduction is How to Spend $75 Billion to Make the World a Better Place (http://www.amazon.com/Spend-Billion-World-Better-Place/dp/1940003016). It is important to realize we don't rank problems – we rank solutions as to which give the biggest bang for the buck. Climate is a definite problem, but unfortunately, some of the often-invoked polices (dramatic cuts in developed word CO_2 emissions in the short run—like Kyoto or the EU 20/20/20 policies) are poor solutions in that they have high costs, and low benefits. That is why we emphasize smart solutions to climate (like R&D into green energy) and point out that there are many other areas where we can do more good, faster, quicker first (like focusing on nutrition, malaria prevention, agricultural productivity etc.)

Q4. A recent survey found that worldwide concerns about climate change are at a 20 year low, far fewer than at the beginning of the global financial crisis. Part of this decline is attributed to a backlash against expensive green energy investments. Can you elaborate on the impact that high electricity prices can have on a household budget during a time of increased budgetary pressures, and how climate mitigation strategies such as costly renewable energy might negatively impact the poor?

A4. It is clear that when current green polices cause significant economic hardship (German electricity prices have increased 61% since 2000), while doing little to help tackle global warming, the long-term impact is a loss of confidence in the policies. That's why I think the only long-term sustainable policy solution to global warming is one that is smart according to a cost-benefit analysis, such as R&D for green energy.

Q5. Following the hearing, Dr. William Chameides wrote[1] about your policy recommendation that, "A standalone policy like that is unlikely to get us to where we need to be. We need a

[1] http://blogs.nicholas.duke.edu/thegreengrok/house-hears-about-climate/

portfolio of policies, and those policies will be most effective if they are anchored by a comprehensive, nationally uniform price on carbon dioxide emissions. Complementary policies, such as fuel economy standards, building codes and renewable portfolio standards, as well as funds for research and innovation will also be needed to ensure progress where market failures and institutional barriers limit the effectiveness of a carbon-pricing system." Do you agree?

A5. I think everyone agrees that all policy solutions should be invoked (in economist speak: it is very unlikely that the best solution is a corner solution). Both adaptation, mitigation and R&D has a place. Our disagreement is more on the emphasis. I understood on Professor Chameides that he would emphasize mitigation. I think the data clearly shows that this strategy has a hard time working and is very costly, and hence I would accord a bigger emphasis on R&D.

Appendix II

Additional Material for the Record

SUBMITTED STATEMENT BY EDDIE BERNICE JOHNSON, RANKING MEMBER, COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

Mr. Chairman, thank you for calling this hearing today. Climate change is one of the greatest challenges facing our Nation, and indeed, the entire world. Unfortunately, since the Republican Party took over the House in 2011, the issue of climate change has been largely ignored. This is a problem that cannot be dismissed. Putting our heads in the sand and hoping for the best is a recipe for disaster. So I am glad we are having this hearing today, and I hope it is the first of many.

The science surrounding this issue reached a consensus a long time ago, and that consensus is that the world is warming and most of that warming is being caused by humans. In our own country, organizations like the National Academy of Sciences, American Association for the Advancement of Science, American Chemical Society, American Geophysical Union, American Meteorological Society, American Physical Society, and the Geological Society of America have all acknowledged this. Moreover, these prestigious organizations have been joined by national academies of science from numerous countries around the world, including the United Kingdom, France, Germany, Mexico, Canada, Russia, China, Brazil, India, and Japan among many others. It has been reported that since 2007, not a single scientific society of national or international standing maintains a formal opinion dissenting from this fundamental point. The consensus is literally overwhelming.

Unfortunately, many of my colleagues in the Majority don't seem to have gotten the memo. Many openly dispute the science or allude to some unspecified but supposedly vast scientific conspiracy. Others, while less conspiratorial, insist that nothing can be done about the problem. This is a failure of leadership of the highest order.

Many prestigious organizations and individuals have laid out the terrible economic consequences of inaction, including in recent reports by the World Bank and the World Economic Forum. These organizations also note that the brunt of these effects will be borne by people around the world who can least afford to deal with them. A slow motion human tragedy could be unfolding before our eyes, and it is unconscionable for us to sit and watch it progress when we know how to avoid it.

So I am happy we are having a hearing on this important issue. I am also pleased that the Majority has called a witness, Dr. Lomborg, who in both his current testimony and previous testimony in Congress, has supported placing a price on carbon and dramatically increasing green energy research investments. These types of solutions may not be easy, but they are absolutely critical to ensure that we don't pass a terrible problem onto our children and grandchildren.

Mr. Chairman, I hope that this hearing will mark the start of a serious conversation on the Committee about climate change, and I hope it will be followed by hearings with testimony by the organizations I've cited.