July 29, 2014

EXAMINING THE THREATS POSED BY CLIMATE CHANGE

U.S. SENATE COMMITTEE ON ENVIRONMENT & PUBLIC WORKS, SUBCOMMITTEE ON CLEAN AIR AND NUCLEAR SAFETY

ONE HUNDRED AND THIRTEENTH CONGRESS, SECOND SESSION

HEARING CONTENTS:

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Mr. Carl G. Hedde, CPCU ***[view pdf]***
Head of Risk Accumulation
Munich Reinsurance America, Inc.

Hon. Kristin Jacobs ***[view pdf]***
Commissioner
Broward County, FL

Mr. Bill Mook ***[view pdf]***
President
Mook Sea Farm

Dr. Bjorn Lomborg ***[view pdf]***
Ph.D. and Adjunct Professor
Copenhagen Consensus Center, Copenhagen Business School

Raymond J. Keating ***[view pdf]***
Chief Economist
Small Business & Entrepreneurship Council

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Testimony at U.S. Senate Subcommittee on Clean Air and Nuclear Safety hearing, "Examining the Threats Posed by Climate Change."

July 29, 2014

Carl Hedde, Head of Risk Accumulation, Munich Re America

Introduction

Good afternoon and thank you for inviting me to testify. I am Carl Hedde, Head of the Risk Accumulation Department at Munich Reinsurance America, Inc. Founded in 1917, Munich Reinsurance America, Inc. is one of the largest reinsurers in the United States. We have earned the A+ (Superior) financial strength rating from A.M. Best Company, and have over 1,000 employees serving our clients from our Princeton, New Jersey campus and regional offices throughout the United States. Our parent company, Munich Re, is one of the world's leading reinsurers, taking on global risks of every type and complexity for insurance companies and large corporations. In addition to my role with the Munich Re Group, I serve on the Board of Directors of the Institute for Business and Home Safety (IBHS), and am the immediate past chairman of the IBHS Board.

One significant component of our business is providing catastrophe risk insurance to our clients. Due to our history of insuring natural catastrophes (Nat Cats), Munich Re was one of the first companies in the industry to recognize the impact that weather-related events and a changing climate could have on its business model and customers.

To address this, the company formed a GEO Risks research unit 40 years ago. The department's goal is to assess scientific research around weather and geophysical events, contribute to scientific discussions with our own research, and feed scientific findings into our business model, where applicable. The GEO Risks group also studies the impact of catastrophic events through a thorough analysis of historical loss patterns. This work helps us to better understand and incorporate this knowledge into our underwriting decisions.

The insurance industry relies heavily on historical loss information to make business decisions. However, the use of historical data assumes that the risk we see today is the same as it was in the past. This is not always the case. If a clear, verifiable trend is identified in relation to a certain risk, the trend must be taken into account in the models for them to yield meaningful risk estimates.

One area where we do see an upward trend is in regard to losses from weather catastrophes, which, over time, have increased in both frequency and severity. In the U.S., socioeconomic changes have played a substantial role in this increase, but do not explain the entirety of the changes. It is likely that changes in climate, whether from natural variability or due to man's influence, are also playing a role in these trends.

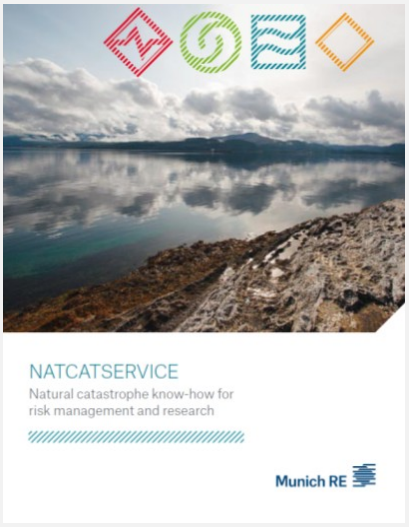
Today, I will provide an update on Nat Cat activity, as well as examples of short- and long-term adaptation efforts for the extreme weather events our country will continue to face.

Munich Re Nat Cat Service Database

The source for the majority of the information I will share is the Munich Re Nat Cat Service database. Comprised of some 35,000 events, it is the most comprehensive Nat CAT database in the world. It includes worldwide data on all relevant loss events from 1980 to today, and data on all relevant loss events since 1970 for the U.S. and some European countries. Approximately 800 - 1,000 new events are recorded and analyzed each year.

Free access to much of the data is available through the Munich Re NatCatSERVICE Download center on the company website (http://www.munichre.com/en/reinsurance/business/non-life/natcatservice/index.html).

MR NatCatSERVICE
The world's largest database on natural catastrophes



The Loss Database Today

- **From 1980 until today all loss events; for USA and selected countries in Europe all loss events since 1970.**
- **Retrospectively, all great disasters since 1950.**
- **In addition, all major historical events starting from 79 AD – eruption of Mt. Vesuvio (3,000 historical data sets).**
- **Currently more than 35,000 events**

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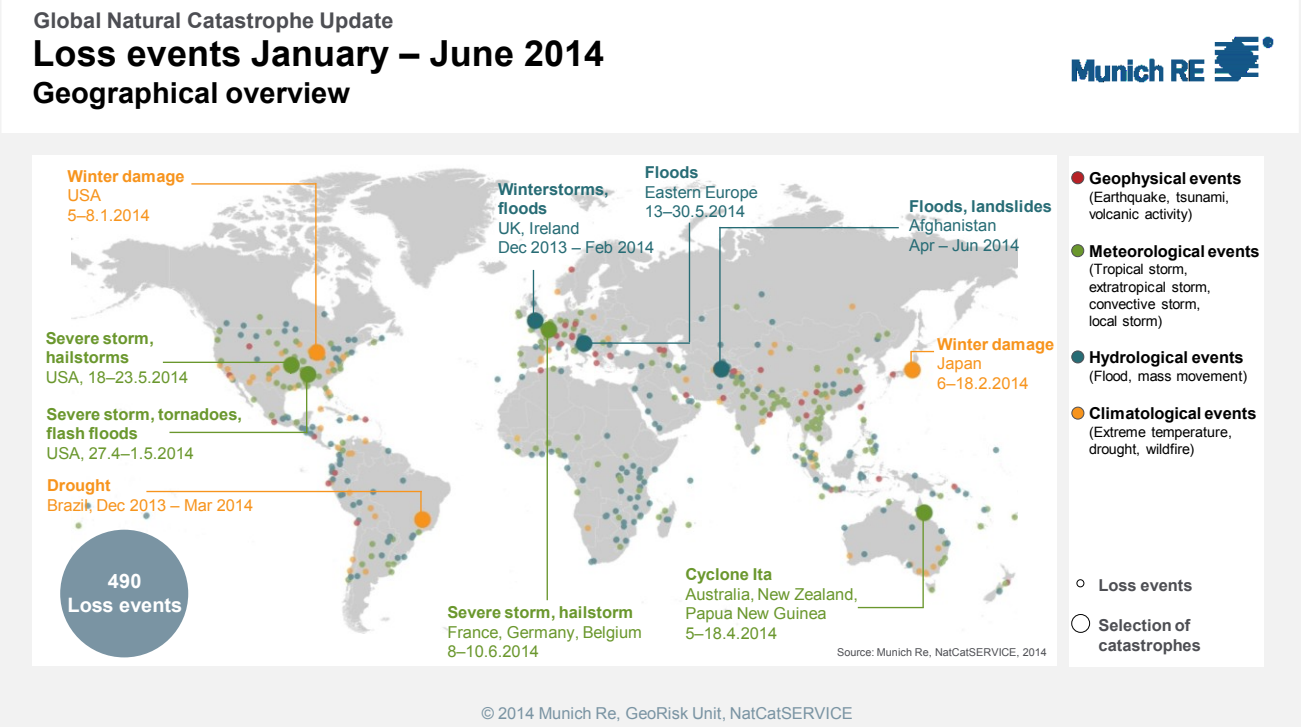
Global Catastrophes First Half of 2014

Globally, there were close to 500 loss events due to Nat Cats in the first six months of 2014. Extraordinarily hard winter conditions affected the US and Japan, while parts of Europe suffered from heavy rainfall, storms and floods.

While it was cold in some parts of the globe during the winter of 2014, it was not cold everywhere. Alaska and Greenland were much warmer than normal, as was most of Europe, north Africa, and China. The average global temperature in January 2014 was 1.17 degrees Fahrenheit warmer than the 20th century average.

Worldwide, direct economic losses totaled $42 billion and insured losses totaled $17 billion for the six month period, well below the six month average of $94 billion for the last 10 years. About 2,700 lives were lost as a result of these global disasters, much lower than the 10-year average.



U.S. Natural Catastrophes First Half of 2014

In the US, 67 Nat Cat events caused over $14 billion in economic losses and over $10 billion in insured property losses during the first half of 2014, accounting for over 60% of the global total. The insured loss total is below the 2000 to 2013 average of $11 billion for the same six-month period.

Insured losses due to thunderstorm related perils, such as tornadoes and hail, during the first six months of 2014, are estimated at $7.8 billion, accounting for almost 80% of the half-year total insured loss. This is the lowest half-year total since 2007, due primarily to prolonged winter conditions across the eastern US, which resulted in a late start of the spring thunderstorm season.

As previously noted, the eastern US experienced a very cold winter. From January to March, Arctic air masses repeatedly moved southward into the US, causing extended periods of unseasonably cold weather. Many cities experienced low temperatures not seen in almost 20 years. The cold air also allowed for the development of numerous winter storm events, some reaching as far south as the Florida Panhandle. In all, the prolonged winter caused an estimated $2 billion in insured losses, well above the 2009-2013 average of $1.3 billion.

Insured losses from other natural perils during the first half of 2014 were minimal, but a few events are noteworthy. Although drought conditions eased in some locations, conditions in California worsened, and the state is now experiencing one of its worst droughts. Dry conditions there caused an early start to the state's wildfire season, with fires scorching 29,000 acres and destroying 60 buildings in San Diego County in May. Continuing drought conditions in the state may increase the likelihood of large fires during the state's usual autumn fire season.

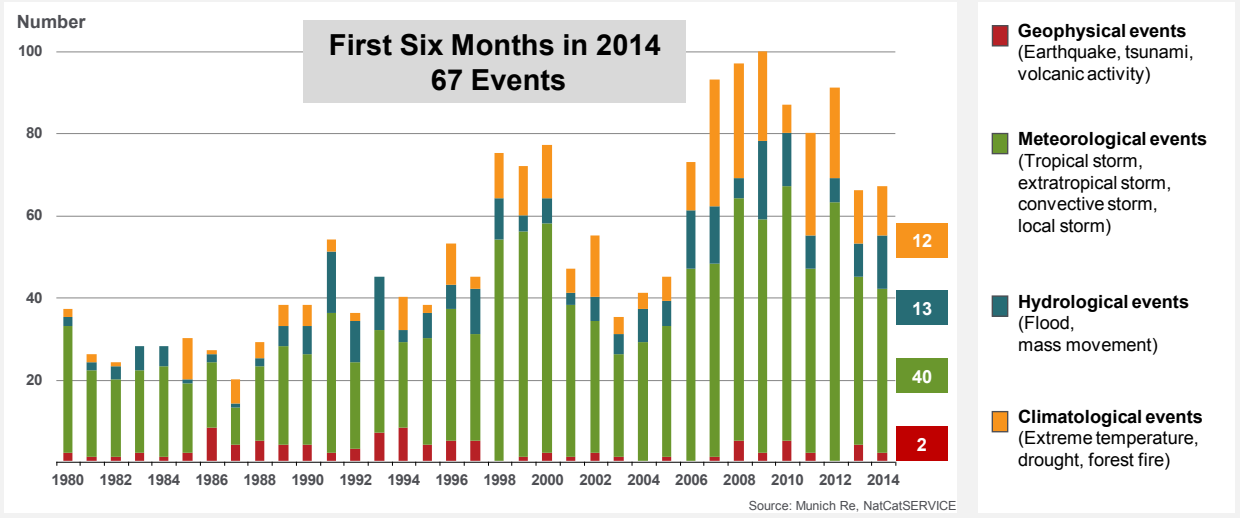
Two geophysical events also caused insured losses during the first half of the year. Excessive rainfall caused a massive landslide in Oso, Washington, that destroyed homes and took 44 lives. And after years of relative quiet, there was a magnitude 5.1 earthquake in the Los Angeles Basin that caused minor insured losses.

Through the first six months of the year, the US did not experience any landfalling Tropical Cyclones. This changed with Hurricane Arthur along the North Carolina Outer Banks during the July 4th weekend. Estimated losses from Arthur are below $250 million, due in part to strict building codes in the region.

US Natural Catastrophe Update

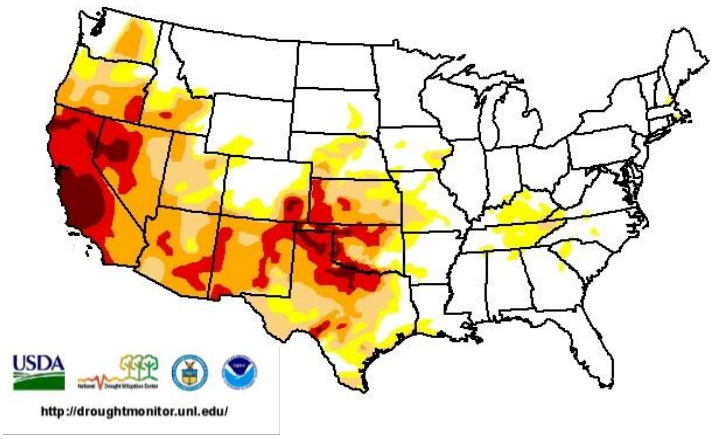
Loss events in the U.S. 1980 – 2014

Number of events (January – June only)



US Natural Catastrophe Update

Current U.S. Drought Conditions



Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	58.58	41.42	29.26	20.73	9.38	2.43
Last Week 6/17/2014	58.64	41.36	29.70	21.25	9.71	2.62
3 Months Ago 3/25/2014	56.07	43.93	31.99	19.29	8.10	1.75
Start of Calendar Year 12/31/2013	54.20	45.80	26.01	13.96	3.31	0.31
Start of Water Year 10/1/2013	44.21	55.79	37.21	17.33	2.56	0.24
One Year Ago 6/25/2013	49.41	50.59	38.12	26.78	10.98	3.65

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Trends

I would now like to talk about the upward trends we see in relation to Nat Cat events globally and in the US.

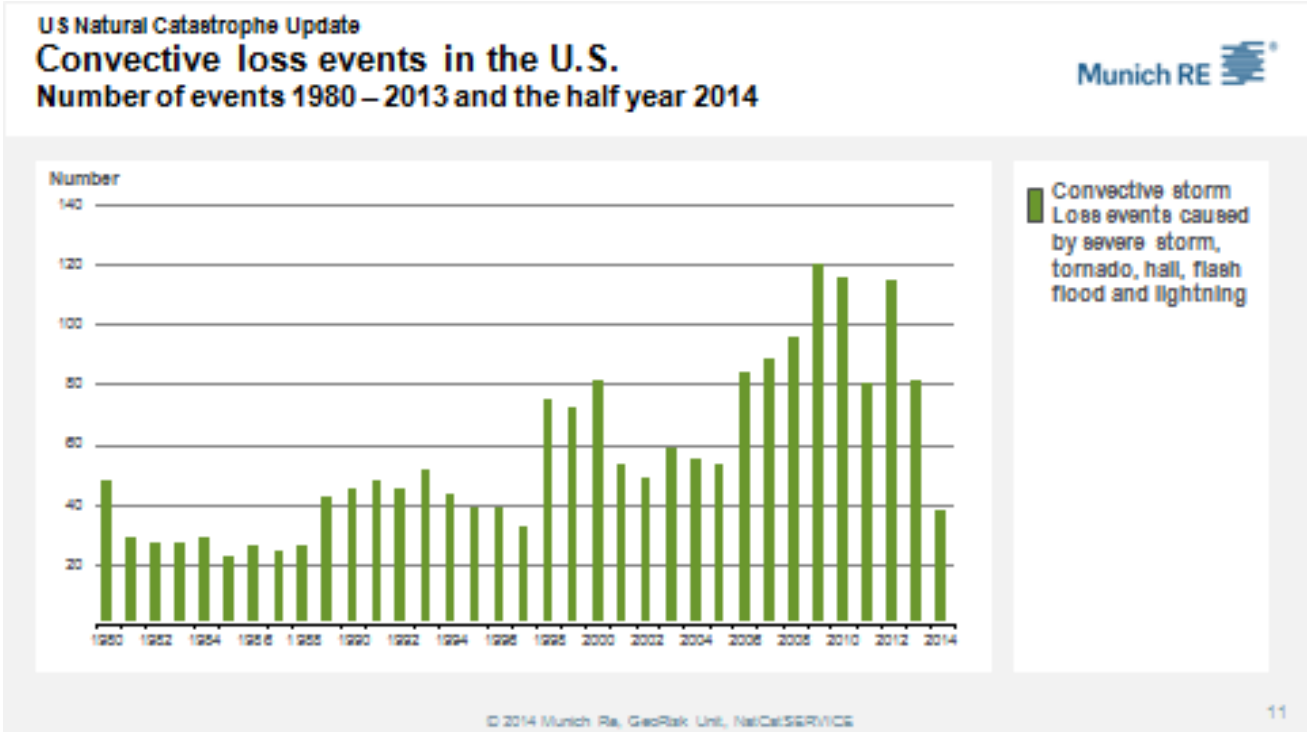
When we look at the worldwide annual totals of geophysical loss events, like earthquakes and volcanic eruptions, we see that they have stayed very constant over the past 35 years. Where we see an upward trend is in the increasing number of weather related loss events around the globe, as well as climatic events, such as drought and heat waves. The US, for example, observed the second highest percentage increase in the period 1980-2013 (after Asia), with respect to the number of weather-related loss events.

As noted previously, a significant proportion of the increase in the number of catastrophe loss events is due to socioeconomic changes in the US over the past few centuries. This is particularly the case for small loss events that either would not have been observed or reported in the past; or for events that occur in locations that only recently have been developed. However, socioeconomics likely do not explain all of the increase we have observed in our data.

For example, our research shows that, since 1970, there has been an increase in the frequency and variability in the large-scale atmospheric conditions that allow severe thunderstorms to develop over the eastern two-thirds of the US. If we then look at normalized losses from large thunderstorm events in the US since 1970 (those causing an economic loss greater than $250m), we can see the same pattern in the loss data as the meteorological data - an increase in the number and variability of large loss events over the latter half of the 1970-2009 period.

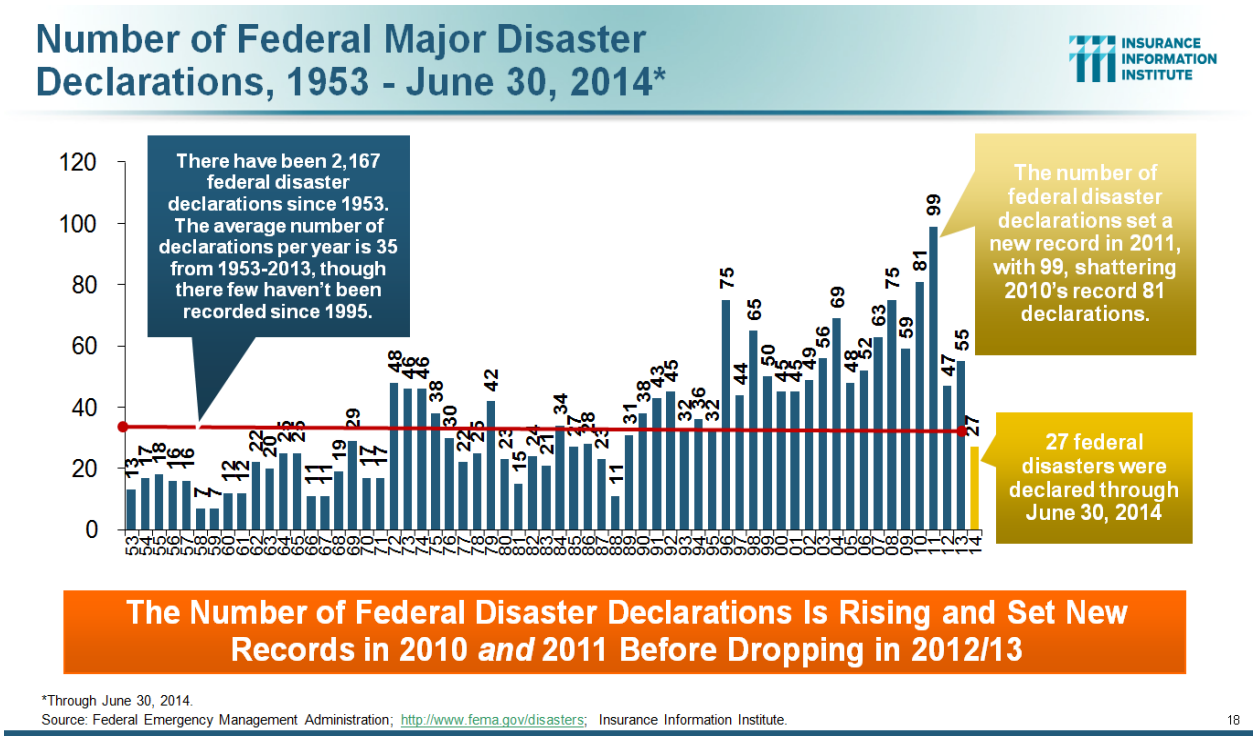
This shared pattern is a “fingerprint” of changes in a meteorological parameter influencing changes in observed losses patterns. In a peer reviewed study by Munich Re, no final attribution of the climatic variability identified in thunderstorm forcing and losses—either to natural climate variability or to anthropogenic climate change—was conclusively arrived at. Nevertheless, the expected impacts of anthropogenic climate change on the forcing of convective storms appear consistent with these findings.

Other perils we note in respect to notable upward trends are drought, flood, and wildfires. According to the Intergovernmental Panel on Climate Change (IPCC), anthropogenic climate change is expected to bring large-scale changes to the hydrological cycle, and in many regions, wet areas are expected to get wetter and dry areas drier. Examples of such patterns are the extended drought over the past decade in the US southwest and California, which in turn has an impact on the potential for large wildfires in the region. Regarding flood, since a warmer atmosphere can hold more water vapor, we would expect in a warmer climate to see more extreme precipitation totals from some rainfall events. This is an effect of a warming climate that we already see in the historical data.



Adaptation

While it is good news that Nat Cats in the US have been relatively mild so far in 2014, we should not forget that there has been no change in the overall catastrophic risk situation of the nation. Our buildings and infrastructure are very vulnerable to Nat Cats, and future large loss events are inevitable, regardless of climate change (though climate change would worsen this situation). We must, as a nation, learn from past loss events, then use what we learn to reduce losses from future events.



Over the past two decades, we have learned that working to prevent losses to buildings is a critical component in reducing catastrophe losses, and should be at the forefront of our considerations. Munich Re, the IBHS, and other insurers have recently begun discussions with the federal government on how to make our country more resilient to extreme weather events. We support a smart, balanced approach that protects the public, but does not stifle business or innovation.

We need to construct homes and businesses that are more resilient in the face of weather events. According to an IBHS test of homes built to state code in Illinois, for less than approximately 3% of the cost of a new home, we can make them more resistant to all but the strongest of windstorms. For every house that is not destroyed by a hurricane or tornado, there is a family that is not temporarily displaced or financially burdened by the event and, most importantly, is more likely to survive the storm. A reduction in damage across whole communities also means that economic life can continue uninterrupted, with less reliance on insurers and the government to recover. In short, building disaster-resistant homes and businesses is a beneficial scenario for everyone, including federal, state and local governments – and taxpayers.

Munich Re actively supports adaptation efforts around the globe. In the US, we encourage stronger building codes which have been shown to decrease risk. For example, homes built in accordance with Florida building codes in effect since 1996 see a 42% reduction in mean damage, as compared to homes built before 1996. Fortunately, adaptation activities have also proven to be cost effective. The investment to make a building more resilient to wind is paid back to the investor many times over through a reduction in future losses. For example, a study by the

National Institute of Building Sciences found that, on average, $1 spent on disaster-risk mitigation and preparedness saves an average of $4 in future losses.

In addition to the IBHS Fortified Home program, Munich Re supports further development of the Resilience STAR Program – a public-private partnership initiated by the Department of Homeland Security, with the goal to build and retrofit homes to be more disaster-resistant. Currently, federal and state governments provide post-event subsidies to citizens in the form of disaster assistance. If other financial incentives, such as government tax credits, rebates, or mortgage considerations were provided to incentivize the building of wind-resilient structures before an event (similar to incentives provided through the Energy Star program for home appliance systems), it would save lives and money. As homes become more resistant to natural catastrophes, losses will decline, and insurance premiums should ultimately reflect the lower risk.

The insurance industry and government can also work together to expand the privatization and insurability of flood risk. Risk-adequate rates and the development of third party commercial flood models will help promote the development of a viable commercial flood marketplace.

Munich Re and the insurance industry help individuals and communities rebuild their lives after extreme events; provide relief for government budgets by sharing in the cost of recovery and rebuilding efforts; make national economies more resilient after catastrophes; provide financial solutions for private sector and governmental/public risks; drive loss prevention strategies based on vast risk management expertise; support research and implementation of prevention measures to reduce risks; and play an active role in raising public awareness of disaster risks and adaptation options.

However, the insurance industry only covers a portion of the loss from natural catastrophes; ultimately taxpayers pay for the rest. As a nation, we need to take steps to reduce the societal impact of weather events as we see greater variability and volatility in our climate. It is in the mutual interest of the federal government and the insurance industry to partner to find solutions in the areas of adaptation and risk transfer. This makes absolute sense from a macroeconomic perspective, as lower subsequent losses will generate savings of several times the investment. Most importantly – these solutions can protect human lives.

Thank you again for providing this opportunity for me to testify.

Written Testimony - Kristin Jacobs, Commissioner, Broward County, FL
Environment and Public Works Clean Air and Nuclear Safety Subcommittee
July 29, 2014

Good Morning, Mr. Chairman.

I would like to personally thank you for your leadership and for convening this hearing today.

As you know, Florida, especially south Florida, is extremely vulnerable to the effects of climate change. Our extensive coastline, low land elevations, flat topography and unique geology combine to put south Florida communities on the front line for combatting climate impacts.

During my 16 years in public service as a Broward County Commissioner, I have been dedicated to addressing the issue of climate change. Sea level rise is one of our most pressing concerns, but there are many other effects of climate change that we're experiencing. And as we know, impacts are not isolated to the nation's coastlines, or restricted to city limits, county lines, or state boundaries. They have cascading effects, geographically and economically.

In southeast Florida, the hazards are diverse and include coastal and inland flooding, storm surge, saltwater contamination of drinking water supplies, impacts to water and wastewater systems, beach erosion, and threats to public and private property and infrastructure. We will also experience hotter temperatures, public health challenges such as longer and more severe heat waves, ocean acidification and warming with impacts to coral reefs and fisheries, and additional stresses on the Everglades.

The effects are showing up all around us. In south Florida we have chosen to undertake a regional approach to planning for climate change – one that emphasizes collaboration and collective action. Our journey has been propelled by the shared reality of impacts that are already affecting our communities. Already, we experience extensive flooding during extreme high tide events, with neighborhoods inundated as seawater pours over sea walls, pushes up through storm drains, and rises up through the ground.

Iconic business districts are affected including:

- Duval Street in Key West,
- The famed Alton Road in Miami Beach, and
- Las Olas Boulevard in downtown Fort Lauderdale.

Miami Beach is now undertaking a $200 Million stormwater master plan to combat sea level rise and Fort Lauderdale recently estimated similar improvements at $1 Billion for their system.

While these provide recognizable examples, in reality, the full expanse of our urban landscape suffers from increased flood risk. Due to sea level rise, the discharge capacity of our regional flood control system has been reduced, such that even minor storm events can result in extensive flooding. Severe storm events, another climate-induced impact, further exacerbate risk. We are seeing an increase in the number of record-breaking storms, even during the dry season, including the one-in-a-thousand year storm event this last January when 22 inches of rain fell across Palm Beach County in less than 24 hours.

These changes are necessitating major investments in new infrastructure and system retrofits:

- The South Florida Water Management District has identified 18 coastal salinity control structures as potentially vulnerable to sea level rise. These structures are designed to separate coastal waters from freshwater within our canals. Control gates allow flood waters to discharge during rainfall events. However, as a result of sea level rise, there is less difference between upstream and downstream water levels and discharge capacity is reduced. The result is that during certain high tide events flood gates cannot be opened without saltwater spilling in, and stormwater cannot be discharged. Forward pumps can address the problem; however, installation of these structures is estimated to cost $50 Million each. Six are currently prioritized for retrofit.
- Due to increasing flood risk, the City of Hallandale Beach has been forced to retrofit drainage wells with pumps in order to alleviate flooding at a total cost of $10 Million.
- Following Tropical Storm Sandy, additional beach erosion resulted from prolonged onshore winds during extreme high tides and led to the collapse of 2,000 feet of state road A1A in Fort Lauderdale. The cost of repairing this emergency evacuation route exceeded $21 Million. The community learned from this event and the restored roadway included a resilient redesign with an elevated roadbed, fewer lanes, additional set back, and the creation of buffer dunes.
- In the Florida Keys, the City of Key West, raised a local road by nine inches when warrantees were voided on corroded police vehicles as a result of repeated exposure to tidal flooding. Today, Monroe County is preparing to elevate another roadway by 12 inches due to tidal flooding and in consideration of future sea level rise the County amended plans for a local fire station, raising the site an additional 1.5 feet.
- Further north, in Palm Beach County, the Florida Department of Transportation is planning to raise PGA Boulevard by three feet to address sea level rise and improve stormwater management.

Another impact of sea level rise is the loss of potable water capacity within the Biscayne Aquifer, our region's primary water supply. Sea level rise has accelerated saltwater intrusion and the contamination of coastal wells. As much as 50% of Broward County's coastal well field capacity is considered vulnerable, and replacement with alternative water supplies is estimated to cost $300 Million in our County alone.

Climate impacts affect critical community resources, vulnerable populations, and vital infrastructure. According to the National Climate Assessment (NCA), Miami, like other southern cities, is already seeing an increase in the number of days with temperatures exceeding 95ºF, during which the number of deaths is above average. Within the Southeast, south Florida is expected to see the greatest increase in maximum temperatures. This is of particular concern as many low-income households may not be able to weatherize their homes or operate air cooling systems and Florida already has the highest number of low-income households, and households with elderly members, requiring energy assistance, of states in the Southeast (Climate of the Southeast United States, 2013).

In addition to the threats to public health directly relating to heat exposure, higher temperatures contribute to the formation of smog and allergens. Smog and allergens can trigger asthma attacks and other respiratory illnesses. NCA projections predict an increase in smog in the 19 largest urban areas of the Southeast, leading to an increase in deaths (NCA, Chapter 17).

To reduce community risk and the potential for significant economic losses, adaptation necessitates major investments in upgrading infrastructure, coupled with an aggressive plan to head off the most

severe climate impacts through deep reductions in carbon pollution, the leading cause of global climate change.

The economic implications of a failed response do not allow for inaction. With just 1 additional foot of sea level rise, $4 Billion of taxable property will be flooded in Palm Beach, Broward, and Monroe counties. At 3 feet, that figure rises to $31 Billion.

To provide additional economic scope, southeast Florida is home to two of the nation's most active sea ports and two international airports producing more than $66 Billion annually in economic activity. One-third of our state's gross domestic product is tied to the economics of southeast Florida, and of course nation-wide coastal counties account for 45% of our national GDP. Critical assets, infrastructure, local business and households are the fabric of our economy and, as we know from risk analyses, investments in resilience pay off by a factor of 4:1.

In addition to discussing risk, I would like to highlight some of the ways in which we are planning regionally to help build resilience within Broward County and across southeast Florida. I also hope to underscore why federal action on both climate mitigation and adaptation is critical to our individual and collective efforts.

In 2009 Broward, Palm Beach, Miami-Dade and Monroe counties came together to form the Southeast Florida Regional Climate Change Compact.

We have coordinated on many initiatives to reduce greenhouse gas emissions and to adapt to the climate change impacts we are already seeing and expect in the future.

While we have been recognized both nationally and internationally as a leading example of effective local climate action, I am most proud of the work the staff of each county has done in putting together our Regional Climate Action Plan and collaborating on implementation.

Our regional plan includes 110 recommendations covering a wide array of areas, including:

- Energy
- Water
- Transportation
- Sustainable Communities
- Natural Systems
- Agriculture
- Outreach

While our plan offers flexibility, and allows each individual county or city to decide how best to implement the plan, we are finding that in practice it often makes fiscal and practical sense to work together on specific initiatives. This cooperation has accelerated action throughout our region.

Examples of what we have seen so far include:

- Each of the four counties has formally integrated climate change considerations and sea level rise projections into their comprehensive plans and other planning documents.
- In support of climate adaptation, we are advancing plans for a regional surface water reservoir providing surface water storage, diversion of storm water runoff, and aquifer recharge.

- We have formed a coastal resilience work group to expand the use of coral reefs, mangroves, dunes and other living shoreline projects. When integrated with urban systems, these natural infrastructure elements provide optimum shoreline protection while providing habitat preservation, or restoration.

I would also like to make special note of some of our successful partnerships with the federal government including:

- Technical support from NOAA in developing vulnerability maps and conducting assessments;
- Financial support from the US Department of Energy for the Florida Go Solar initiative to streamline permitting and identify finance strategies to incentivize and facilitate investments in rooftop solar systems;
- A grant from NOAA supported our exploration of "Adaptation Action Areas," a new program under Florida law that allows communities to target climate-vulnerable areas for adaptation investments;
- Broward and Miami-Dade counties have worked with the US Geological Survey to create advanced hydrologic models to assess interactions between sea level rise, stormwater, and potable water supplies;
- Compact partners are currently benefiting from a Federal Highway Administration grant to assess the vulnerability of regional transportation infrastructure to climate change; and
- In just two weeks we will be hosting a south Florida version of Rebuild by Design to foster Resilient Redesign in our urban environment. We are pleased that both HUD and the EPA have offered technical expertise to support this process.

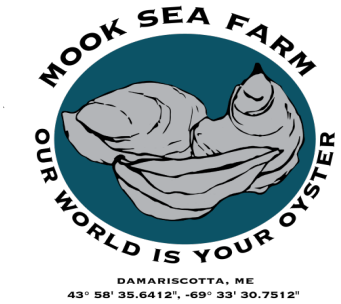
Finally, I have the personal honor and privilege of serving on the President's State, Local and Tribal Leaders Task Force on Climate Preparedness and Resilience. Through the Task Force, state and local government leaders and policymakers from all over the country have come together to talk about the climate impacts they are facing, the solutions they are developing and implementing, and ways we can best work with each other and the federal government to do more to not only limit future climate change, but to live with the impacts we are already experiencing.

Increasingly, it is clear that local governments and regional initiatives like the Compact play a significant role in supporting regional decision making with technical support, expertise, and financial assistance from the federal government. Although the local level is where much of the needed adaptation to climate impacts will happen, we are still in great need of policies at the state, federal, and international levels that reduce carbon pollution and accelerate the transition to a clean energy economy.

I am pleased to share that in this vein, Broward County has committed to a 20% renewable energy goal and our board recently provided unanimous bi-partisan support for the EPA's Clean Carbon Rule, which will result in much needed and long-overdue action that will benefit public health, future generations, and the economy in communities like mine.

Climate change is one of the most important issues facing our region in the 21st century. Please help us make sure that South Florida remains a vibrant, attractive, economically successful region for generations to come. We look forward to continued collaborations with our federal agency partners.

Thank you again for the opportunity to speak to you today.



Testimony of Bill Mook, President of Mook Sea Farm
Before the Senate Subcommittee on Clean Air and Nuclear Safety
Examining the Threats Posed by Climate Change
July 29, 2014

Senator Whitehouse, Senator Sessions, and members of the committee, I am President and owner of Mook Sea Farm, located on the Damariscotta River in mid-coast Maine. In our hatchery, we produce up to 100 million juvenile oysters each year, most of which are sold as "seed" to other oyster farmers from Virginia to Maine. The seed oysters we do not sell, we grow on our 40 acres of leases and sell to the domestic half-shell market as "Wiley Point" and "Pemaquid Point" oysters.

The testimony below provides background and detail about ocean acidification and the threat it poses to marine resources, ecosystems, and those individuals and communities who depend on them. I've been in business for 30 years and, depending on the time of year, my company employs 10 to 14 people including myself. So, because "our world is your oyster," at Mook Sea Farm, ocean acidification has my company's riveted attention.

Shellfish hatcheries are "canaries in the coal mine" for water quality problems because the early life stages we rear are so sensitive to changes in water chemistry. When larval production in our hatchery began to falter about 5 years ago, we started a journey to figure out and solve the problem, which (for now) we have done. We suspected ocean acidification was the root of our problem, and this assumption drove our efforts to change hatchery practices. After seeing the results of our remedies this year, we believe that our hunch was correct.

Our experience, taken together with recent research, leads me to conclude that ocean acidification poses a serious threat to Maine's marine economy. Because the study of ocean acidification is so new, we do not have the information needed to fully "examine the threats" it poses. There are two critical research priorities:

- Water chemistry monitoring; and,
- Understanding species and ecosystem responses to present and future levels of carbon dioxide.

If, and only if, these are addressed, can we plan for the challenges and opportunities posed by ocean acidification.

Ocean Acidification Basics.

The carbon dioxide (CO_2) released from burning fossil fuels doesn't just stay in the atmosphere. About 25% of it dissolves in the world's oceans where it forms carbonic acid. This has resulted in a 30% increase in the average acidity of ocean surface waters since the start of the industrial revolution. The rate of change in ocean pH is accelerating as carbon dioxide emissions increase. By the year 2100, ocean acidity is projected to have doubled. This process is called ocean acidification (OA), and it is occurring at a rate that may be unprecedented in the Earth's history.

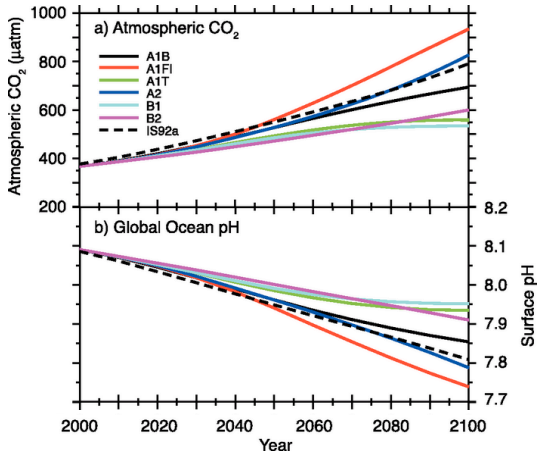


Figure 1. Changes in global average surface pH and under various carbon dioxide emission scenarios. Time series of (a) atmospheric $CO_2$and (b) projected global average surface pH for the six illustrative carbon dioxide emission scenarios Modified from Orr et al. (2005) and obtained from the IPCC Climate Change 2007: Working Group I .

Ocean acidification past, present and future. The top panel in Figure 1 shows how scenarios of projected carbon dioxide emissions will change the concentration of CO_2 in the atmosphere. The lower panel shows the resulting increase in ocean acidity for the various emissions scenarios, which is measured as a decrease in pH.

Acidity is defined as the concentration of hydrogen ions (H^+) in a solution, and is measured using the pH scale, which spans from 0 to 14 with 0 being most acidic, 7 neutral and 14 most basic. The 30% increase in ocean acidity since the industrial revolution referred to above represents a change of 0.1 pH units or a drop from 8.2 to 8.1. The small change in pH is deceiving because the scale is logarithmic (counting on this scale is done as follows: 1, 10, 100, 1000).

Ocean acidification is a new topic for scientific inquiry. Since the first publications in the early part of the last decade, concern about and funding for OA have grown. After only 14 years of study, we have more questions than answers about local acidification processes, how marine

ecosystems will be impacted, and what those impacts will mean for individuals and communities whose livelihoods depend on marine resources.

Complicating factors. The problem is more complicated than the simple dissolution of CO_2 from the atmosphere into the oceans. There are several climatic and oceanographic factors that can exacerbate acidification of coastal oceans:

- Freshwater from ice melt, precipitation, and runoff has low pH and poor buffering capacity (e.g., makes ocean water more likely to change pH in response to CO_2 addition);
- Lower water temperatures mean that more CO_2 can dissolve in the water;
- Wind patterns and submarine topography can create natural upwelling of colder, more acidic, deep water into shallow areas.

In the Gulf of Maine, where my business is located, the exacerbating factor is fresh water. Figure 2 shows the percentage change in very heavy precipitation since the 1950's.

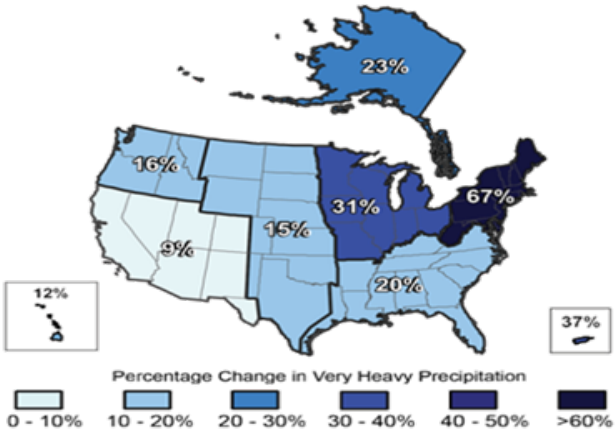


Figure 2. Fresh water from increasing runoff. (Updated from Groisman et al. 2004)

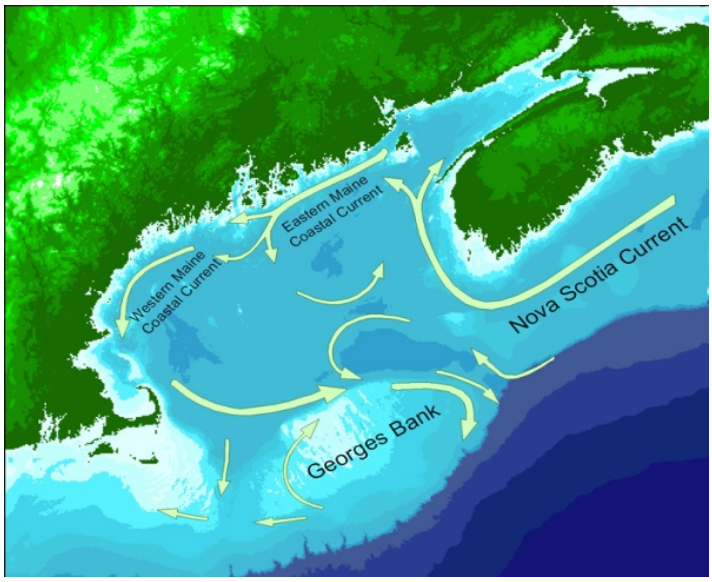


Figure 3. More fresh water from the Scotian Shelf.

To make matters worse, not only is fresh water runoff from the land surrounding the Gulf of Maine increasing, but the Nova Scotia Current is bringing colder, less salty water into the Gulf around the southern tip of Nova Scotia.

How does OA affect marine resources and ecosystems?

With the realization that ocean acidity is increasing, concern in the scientific community initially was focused on shellfish. This is because shellfish, like clams, oysters, scallops, and lobsters, use calcium carbonate ($CaCO_3$) to make their shells. As shown in Figure 4, hydrogen ions increase when CO_2 dissolves in water, and this causes a reduction in the availability of carbonate ions (CO_3), potentially making shell formation problematic.

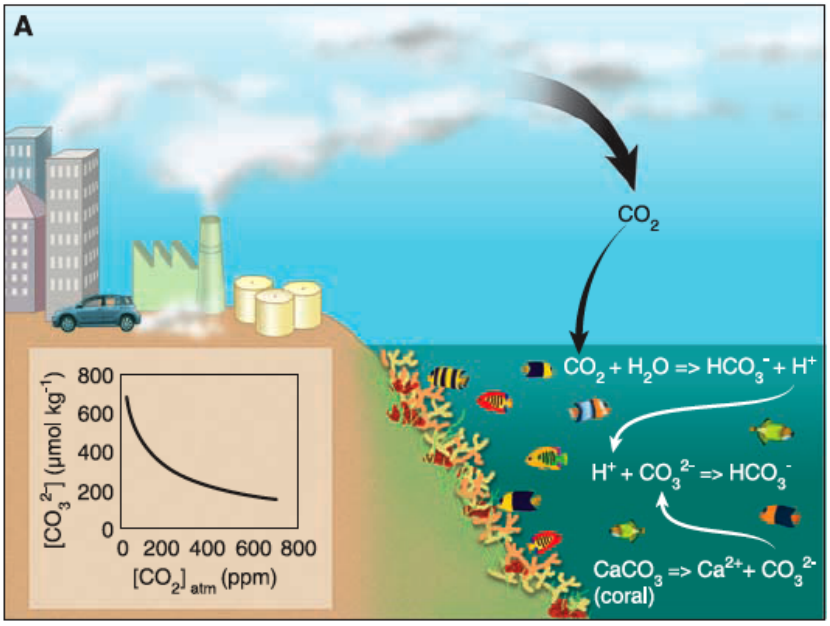


Figure 4. CO_3 availability decreases with increasing acidity.

If populations of harvested bivalves (e.g., scallops, clams, mussels, and oysters) are diminished or eliminated by acidification of their habitats, the losses will not be only financial. In many coastal areas, bivalves perform a vital ecosystem service. They are filter feeders and they keep phytoplankton levels in the water low. This has a cascading effect. Greater water clarity means more light penetrates to the bottom, allowing plants like sea grasses or kelp to flourish. Flora like sea grasses and kelp remove excess nutrients from the water, serve as refuges from predation for smaller prey animals including young fish, and increase ecosystem health and diversity.

From numerous studies conducted over the past 5 years, we now know that acidification of the marine environment will hurt many bivalves. As shown in Figure 5, survival of the free-

swimming, larval phases of bay scallops and hard clams declines as CO_2 in the water increases from pre-industrial atmospheric levels to atmospheric levels seen today (390 ppm) and those expected at mid-century and by 2100.

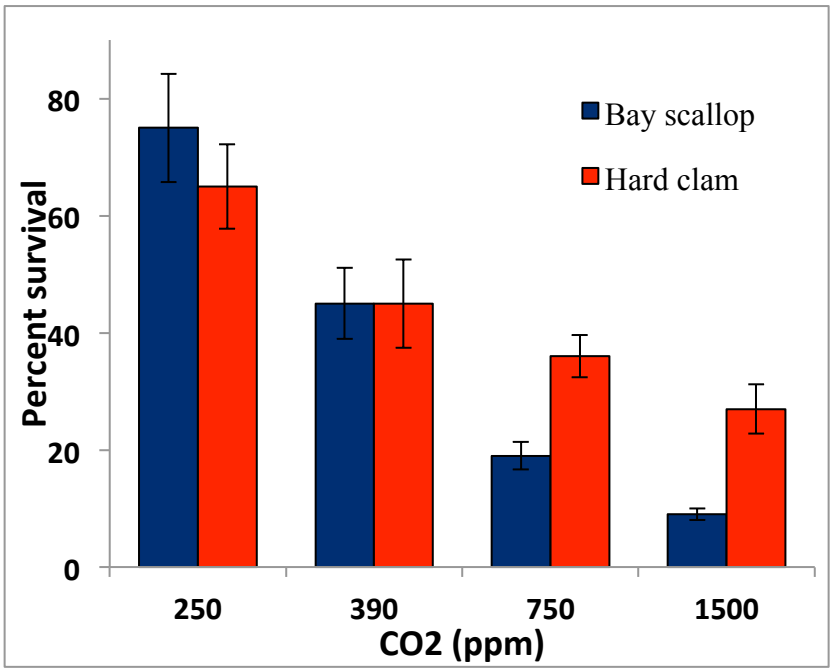


Figure 5. Effects of past, present, and future ocean carbon dioxide concentrations on the growth and survival of larval shellfish (Stephanie Talmage and Christopher J. Gobler. Proceedings of the National Academy of Sciences, volume 107, 2010).

Although larval stages are most vulnerable to high CO_2 concentrations, slower growth rates with increasing acidity have also been documented for juveniles. For both larvae and juveniles, the negative effects of acidification when combined with other climate change parameters, like higher temperatures and low oxygen, can be additive and sometimes synergistic. Recently, researchers have found that some fish species are sensitive to the changes in CO_2. The survival, health, and behavior of species like the Atlantic cod, summer flounder, Atlantic silverside, and even clownfish are compromised in high CO_2 conditions.

While many of these studies were ongoing, at Mook Sea Farm, we were trying to figure out why our oyster larvae were having problems. Fertilized eggs would periodically show poor survival and many of the survivors were severely deformed. More often, larval populations would stall. They would stop feeding and growing and the larval period, which normally lasts 14 to 16 days, would drag on for an additional week or more. These larvae would typically take longer to metamorphose from larvae to juveniles, and exhibit lower survival rates than normal populations. Large storm events seemed to be the common denominator.

The 2009 hatchery season was especially wet and stormy, and we had lots of problems raising larvae. Carbonate chemistry was not on our "radar screen." Late in that year, the first blip showed up. At a meeting with hatchery operators from the West Coast, we learned of their problems (which were similar but more severe) and how they had linked them to the acidified waters pumped into their hatcheries.

Over the next several years we developed a suite of management/mitigation strategies all of which assumed that low pH water was the culprit affecting our larval populations. This season, for the first time, these efforts were all consistently applied to every group of larvae we produced. Since our first spawn in late December we have reared 16 cohorts of oyster larvae. For the first time in my 30+ year career, we were 16 for 16. Every group passed through the larval phase in 14-16 days.

Figure 6. Healthy, swimming American oyster larvae. They are less than 0.2 mm in length at this stage of life.

Through observation, trial, and error, we reached the same conclusion made by researchers using controlled, replicated, experimentation. Acidification is not a future problem. It is a problem ***now,*** and it will only get worse. Further support for this conclusion and cause for concern come from monitoring data we have collected from the incoming water at our hatchery.

For the past several years, we have measured the salinity, temperature, and pH of our intake water on a fairly regular basis. In April of this year, with the help of researchers from the University of New Hampshire, we installed more sophisticated equipment that continuously monitors and records temperature, salinity, dissolved oxygen, and pCO_2.

Other parameters related to ocean chemistry are calculated from the measured values, including the saturation level of calcium carbonate which is represented by the Greek letter omega (Ω). Ω is important because it tells us how easy or hard it is for shellfish to make their calcium carbonate shells. An Ω value of <1.0 means that the water is under saturated with

calcium carbonate; 1.0 means it is saturated; and >1.0 means that it is super saturated. The forms of calcium carbonate commonly used by shellfish to build their shells are aragonite and calcite. They differ in how easily they can dissolve, with aragonite being more prone to dissolution than calcite. One reason oyster larvae are more vulnerable to ocean acidification than juveniles is that their shells are made of aragonite, which is more soluble than the calcite found in juvenile and adult shells.

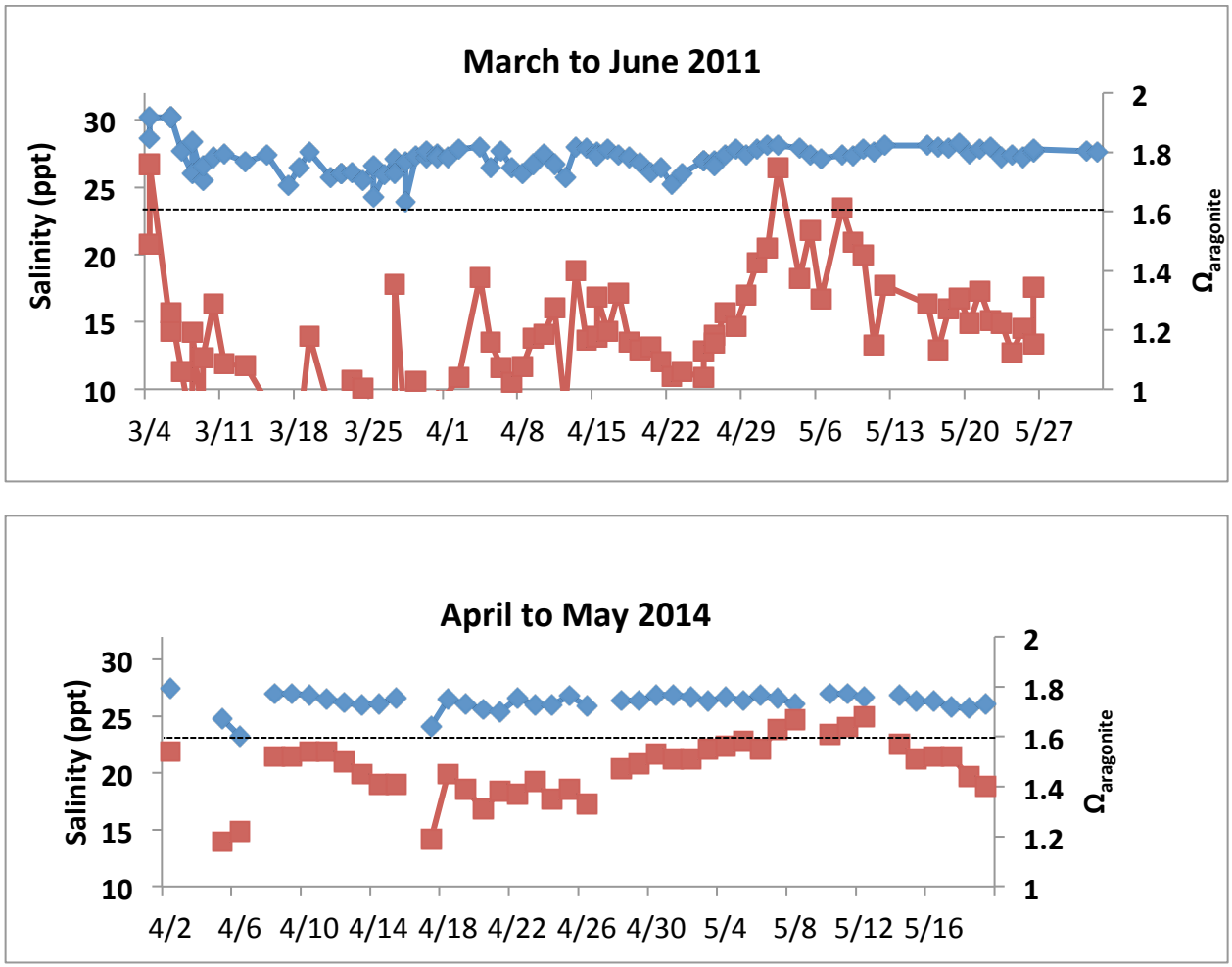


Figure 7. Salinity (blue) and $\Omega_{aragonite}$ (red) of the seawater pumped into our hatchery. $\Omega_{aragonite}$ at 1.6 is indicated by a black dashed line.

Figure 6 shows salinity and $\Omega_{aragonite}$ for spring 2011 and 2014. The $\Omega_{aragonite}$ data shown for 2011 were calculated from temperature and salinity measurements made with hand-held, relatively inexpensive equipment. The data from 2014 were collected with the pCO_2 monitoring equipment. West Coast hatchery operators consider $\Omega_{aragonite}$ values less than 1.6 to be sub-optimal for growing oyster larvae. The studies discussed above found reductions in survival and growth at $\Omega_{aragonite}$ levels even higher than 1.6. What is concerning about the data we have collected is that we rarely see $\Omega_{aragonite}$ exceed 1.6.

While we can manipulate conditions in our hatchery, what is the fate of wild populations subjected to the steady movement of CO_2 into seawater from the atmosphere, exacerbated by extreme variability caused by the increasing number of intense storms dumping more and more freshwater into the Gulf of Maine?

My prediction is: the success of bivalve larvae in coastal waters will become more and more sporadic as acidification progresses, reaching a point where some natural bivalve populations won't occur. There are indications that this process may be under way. At a mussel farm not far from our hatchery, the once predictable appearance of natural mussel seed is now unreliable. Soft-shell clam larvae no longer settle and grow on acidified mudflats in Casco Bay, Maine. Oyster farmers from New Brunswick, who have always relied on collecting larvae from natural populations, are building a hatchery to insure a steady supply of seed.

Figure 8. Mussel seed.

The stakes.

The shellfish industry extends far beyond the farmers and harvesters. As shellfish move through the supply chain, its value increases substantially. Every day enormous quantities of calcium carbonate are trucked around the country by wholesalers who buy from producers and transport shellfish to distributors, who sell to supermarkets, fish markets, and restaurants.

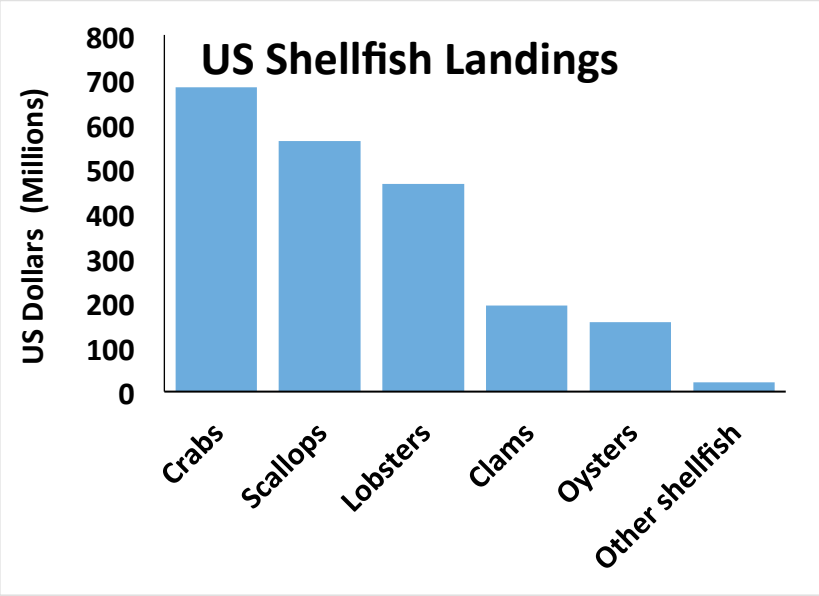


Figure 9. U.S. Shellfish Landings generated over $2 Billion in 2012.

Ironically, even though lobsters and crabs represent over half of the annual landed value of shellfish, we know little about their responses to changes in ocean acidity. This is of special concern to us in Maine, where lobsters are king of marine resources, sustain thousands of people, and are the life blood of communities from Kittery to Eastport.

How do we lessen the negative impacts and take advantage of the economic opportunities afforded by acidification?

We know that negative effects of changing seawater chemistry are a certainty. As with any major change, there will also be opportunities for businesses with knowledge and foresight.

Figure 10. A kelp farm in China. A carbon sink? (Photo credit: George Steinmetz)

Our immediate problem is that we need more information to adequately plan for both the challenges and the opportunities. We need the ability to accurately forecast (at multiple time scales) local changes in key carbonate parameters important to marine organisms and ecosystems. This will require an in depth understanding of the factors that determine these key parameters and how they vary in time and space. In order to develop forecast models, chemical oceanographers need better monitoring at strategic locations.

We know much about the transfer of CO_2 from the atmosphere to the sea, and how temperatures are changing with the accumulation of greenhouse gases. The chemistry (and its variability) for the freshwater inputs are not well understood. Currently, we do not understand quantitatively how changes in the factors which exacerbate acidification will control biological processes that also have profound effects on carbonate chemistry. Photosynthesis by marine plants takes CO_2 out of the water and releases oxygen, but the rate at which this happens may change with acidification. Animals and plants, through respiration, consume oxygen and release CO_2 into their environment. How all of the members of marine ecosystems will respond to ocean acidification is largely unknown. Scientists expect from their knowledge of plant and animal physiology that, at all levels of

the food web, some species will be harmed by acidification, some will benefit, and the structure and function of the communities will change.

Forecasting the pH or Ω of coastal oceans two days, two weeks, or two months into the future is only useful if we understand how species and ecosystems will respond to those conditions. More studies of biological responses to current and future conditions are crucial to providing us with the capacity to plan for the future.

If we make the investment in monitoring and research we can forecast, mitigate, adapt, and re-focus endangered local economies. But this will only buy us time. By taking no action to reduce carbon emissions, we take a huge, uncalculated risk with our future. To those who predict doom and gloom for our economy from curbing greenhouse gases, I would suggest they consider some recent history. Many predicted that the Clean Water Act would cost jobs and stall economic growth. It didn't happen. The same is true for the Montreal Protocol. We switched from underarm spray to deodorant sticks with barely an eye blink. I view the solution to the greenhouse gas as a word problem like the ones we all solved in our school days:

$$\mathbf{L_{Wisdom} + L_{Skill} + BSR + SME + A_{ii} = (G + UB)^{X}}$$

Where **L** = leadership; **BSR** = basic scientific research; **SME** = science and math education; $\mathbf{A_{ii}}$ = American innovation, and ingenuity; **G** = the goal; and, **UB** = unexpected benefits.

The exponent is **X** because when America unites with purpose, the results tend to exceed what can easily be imagined.

Examining the Threats Posed by Climate Change: The Effects of Unchecked Climate Change on Communities and the Economy

Tuesday, July 29 2014, 2:30pm, Room 406, Dirksen Senate Office Building

The Senate EPW Committee, Subcommittee on Clean Air and Nuclear Safety

Testimony by Bjorn Lomborg, Copenhagen Consensus Center

Summary:

Global warming is real, but a problem, not the end of the world. Claims of "catastrophic" costs are ill founded. For instance, even assuming increasing hurricane damage from global warming, the relative impact on society will decrease.

Inaction has costs, but so does action. It is likely that climate action will lead to *higher* total costs in this century.

Climate action through increased energy costs will likely harm the poor the most, both in rich and poor countries.

- The cumulative cost of inaction towards the end of the century is about 1.8% of GDP
- While this is not trivial, it by no means supports the often apocalyptic conversation on climate change.
- The cost of inaction by the end of the century is equivalent to losing one year's growth, or a moderate, one-year recession.
- The cost of inaction by the end of the century is equivalent to an annual loss of GDP growth on the order of 0.02%.
- However, policy action as opposed to inaction, also has costs, and will still incur a significant part of the climate damage. Thus, with extremely unrealistically optimistic assumptions, it is possible that the total cost of climate action will be reduced *slightly* to 1.5% of GDP by the end of the century.
- It is more likely that the cost of climate action will end up costing upwards of twice as much as climate inaction in this century – a reasonable estimate could be 2.8% of GDP towards the end of the century.
- Climate action will harm mostly the poor. Examples from Germany and the UK are given.
- To tackle global warming, it is much more important to dramatically increase funding for R&D of green energy to make future green energy much cheaper. This will make *everyone* switch when green is cheap enough, instead of focusing on inefficient subsidies and second-best policies that easily end up costing much more.

Examining the Threats Posed by Climate Change: The Effects of Unchecked Climate Change on Communities and the Economy

This paper will mostly focus on the economic impact of climate change and the economic impact on communities.

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

It is important to realize that many 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.[1] 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.

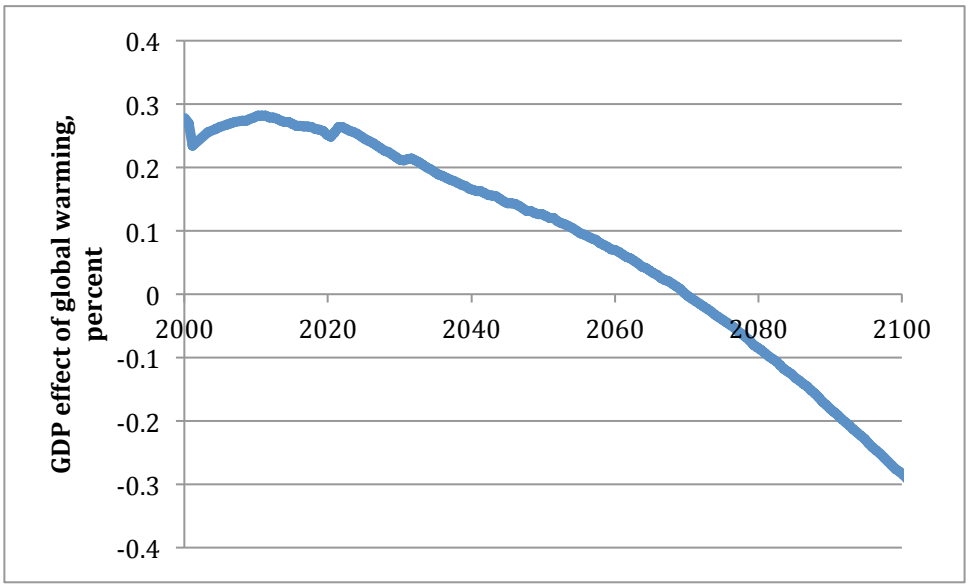


Figure 1 Net benefit or cost of global warming. Benefit is positive, cost is negative.[2]

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 but *negative*, it does *not* signify the end of the world, either. It is a problem that needs to be solved.

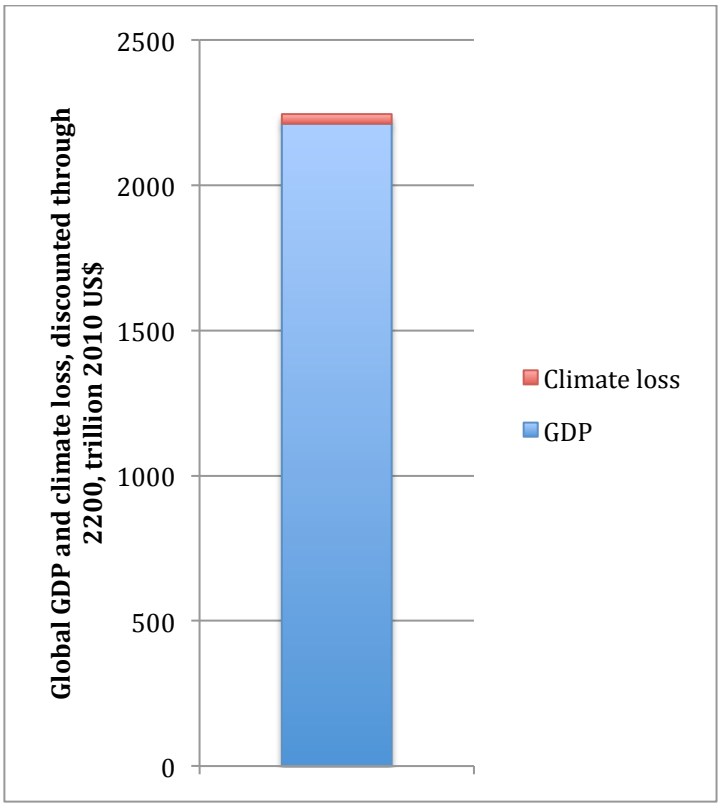


Figure 2 Global, total, discounted GDP through 2200, and climate loss.[3]

What is the impact of unchecked global warming on the US economy? There are a number of integrated climate models. I'll here use Nordhaus' RICE model[4] The model contains 12 regions, including the US, China and the EU, an economic sector and geophysical sectors, linking the economy and climate impacts like sea level rise. It has a equilibrium climate sensitivity of 3.2°C, a bit above average, expecting 3.4°C temperature rise by 2100 in the base scenario. Remember also, that the costs of the risks of abrupt and catastrophic climate change are included in the damage estimates in the RICE model.

The RICE model shows instant damages from temperature, making it more pessimistic than most estimates, as referenced above. Moreover, the model shows a 1.95% GDP loss in 2075 from unrestricted global warming at 1.95°C. The IPCC found that the cost of 2°C higher temperatures would be 0.2-2% of income.[5] This means that the RICE model, if anything, is at the high end cost estimates of the integrated models.

The RICE model show the total, discounted GDP for the US across the next 5 centuries is about $842 trillion (2005$), but this will be reduced by about $10 trillion from cumulative impacts from global warming, as indicated in Figure 3. This means that the total damages from unchecked global warming for the US is on the order of 1.2%.

This indicates, as has often been pointed out, that the US is *less* vulnerable to climate change, compared to many other regions (especially the poorer countries). Moreover, it emphasizes that while the global warming impact is *a net negative* for the US, it is in no way a catastrophe, either.

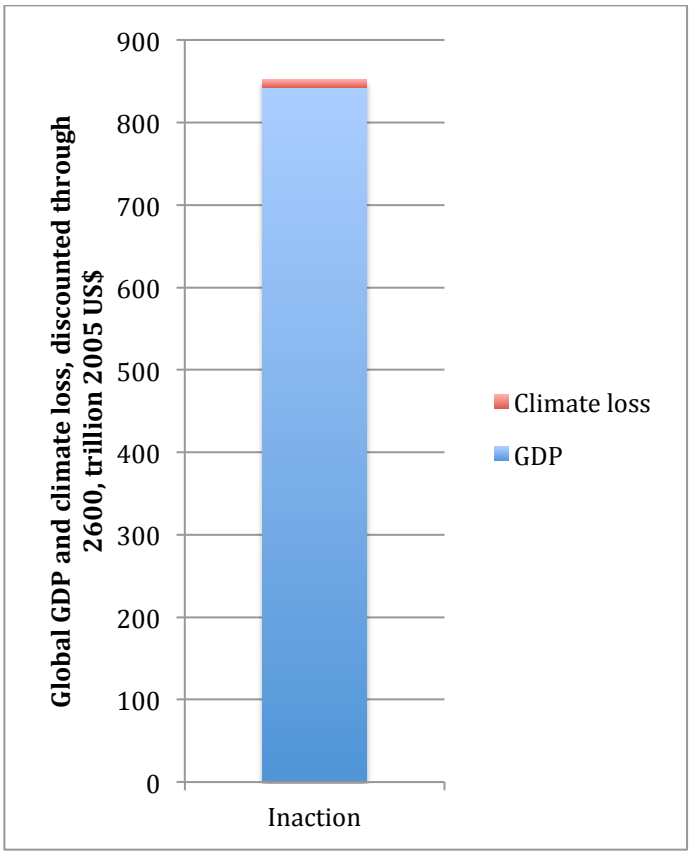


Figure 3 Total US, discounted GDP through 2500, and the cost of unchecked climate change.[6]

However, this is not actually the avoidable impact from climate, since some climate impact will happen no matter what we do. The internationally most ambitious target (which is probably almost out of reach) is the 2°C goal. Figure 4 shows the cost of unmitigated global warming in the upper line, reaching a US cost of 1.8% of GDP by 2100. The lower, 2°C line shows a cost that is almost indistinguishable for the first decades, leveling off just below 0.6% of GDP by 2100. Thus, the avoidable global warming is the area between the two lines, or about 1.2% GDP by 2100.

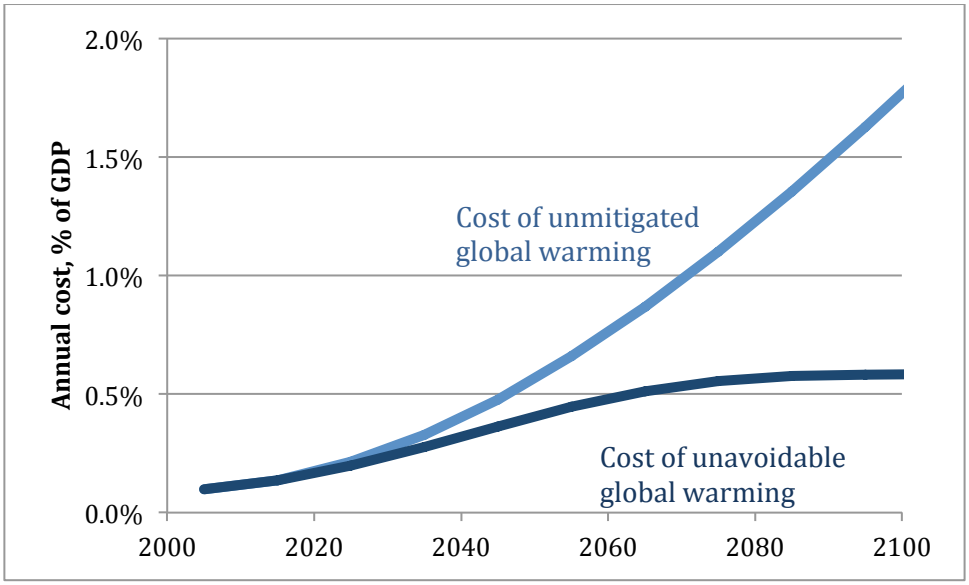


Figure 4 US cost for each year, in % of US GDP that year. Upper line shows the cost of unmitigated global warming. Lower line shows the unavoidable cost of global warming, if all nations achieve the most efficient policies to reach the 2°C target. All calculations from RICE.

The RICE model show the total, discounted GDP impact of global warming for the US across the next 5 centuries is $10 trillion, as mentioned above, while the cost of the unavoidable global warming is about $3 trillion. This means that the total avoidable damages from global warming for the US is on the order of 0.8%.

Policies to avoid global warming also have an impact on the US economy. While unchecked global warming carries a significant cost, any not merely symbolic climate policy will also carry a significant cost.

One way to see that is to correlate economic growth and CO_2 emission growth, as in **Error! Reference source not found.**. Here it is evident, that there is a very strong link between the two. Simply put, as long as the world gets most of its energy from fossil fuels, and cheap energy is the driver of economic growth, it is difficult if not impossible to dramatically reduce CO_2 emission growth without also reducing economic growth.

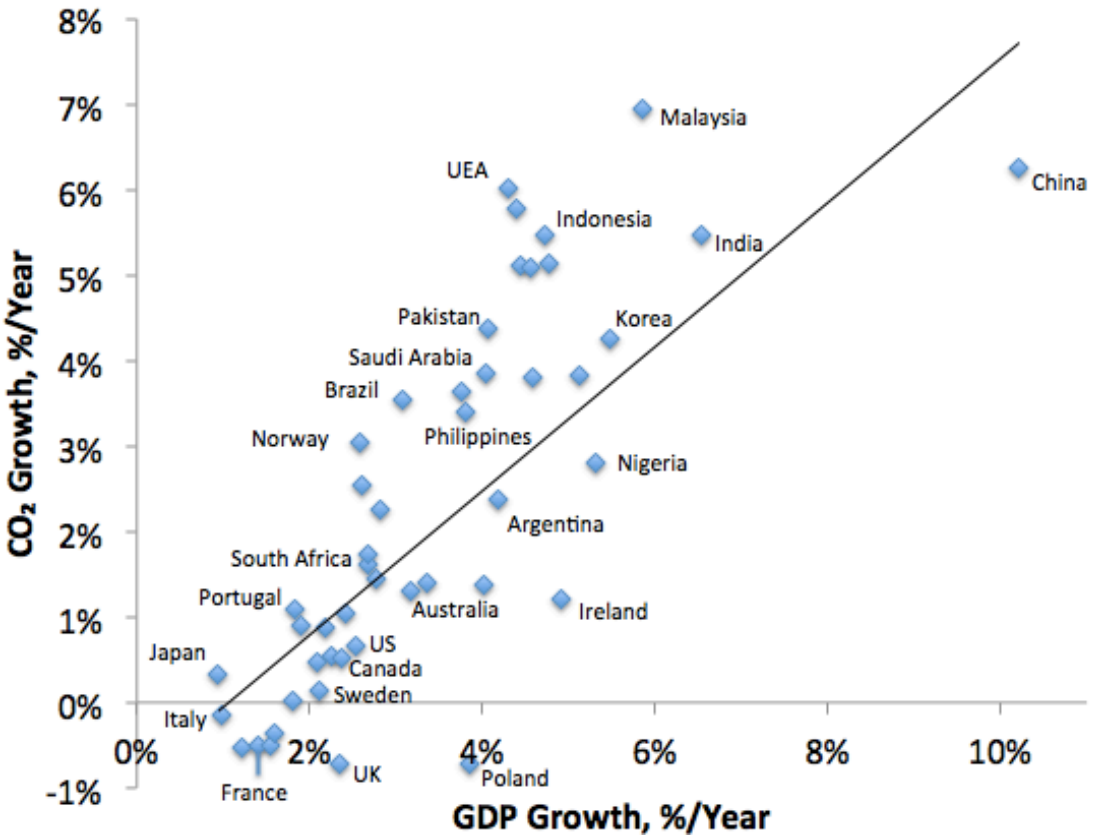


Figure 5 Economic growth per year 1990-2010 vs. CO_2 growth per year for the same period. Best fit line added.[7]

Yes, China and India can reduce their emission growth, but at cost of becoming more like Korea, with lower emission growth and lower economic growth. Similarly, the US can reduce its emissions, but at the cost of becoming more like Italy or France, with lower emission growth or even emission reductions, but similarly, with lower economic growth.

It is important to remember that the cost of global warming is not the only impact on the US economy or the federal budget. Any climate policy enacted to (partially) counter global warming will also carry both costs and benefits. These will indirectly, through policy, impact both the US economy and the federal budget.

The 2°C policy. Consider the world implementing the widely promised (but fairly unlikely) 2°C implemented in the most efficient way possible. This would entail a single, global, uniformly imposed carbon tax, which would increase rapidly through the century. In the RICE model, the indication is that the global carbon tax would have had to be \$19/ton CO_2 in 2010, and would have to be \$26 in 2015 and \$16 in 2020, about \$170 in 2055 and \$296 in 2105.[8]

To give an indication, this would add ¢22 to a gallon of gasoline about now and \$3.40 to a gallon of gasoline in 2085, across the world, including the poorest places on earth.

This is already politically very unlikely to happen. Moreover, the cost is likely a low estimate. Another survey of a 8 global energy models showed the 2°C target might cost in the order of 12.9% of GDP by the end of the century, leading to carbon taxes of four times the RICE model at \$4004 per ton CO_2.[9]

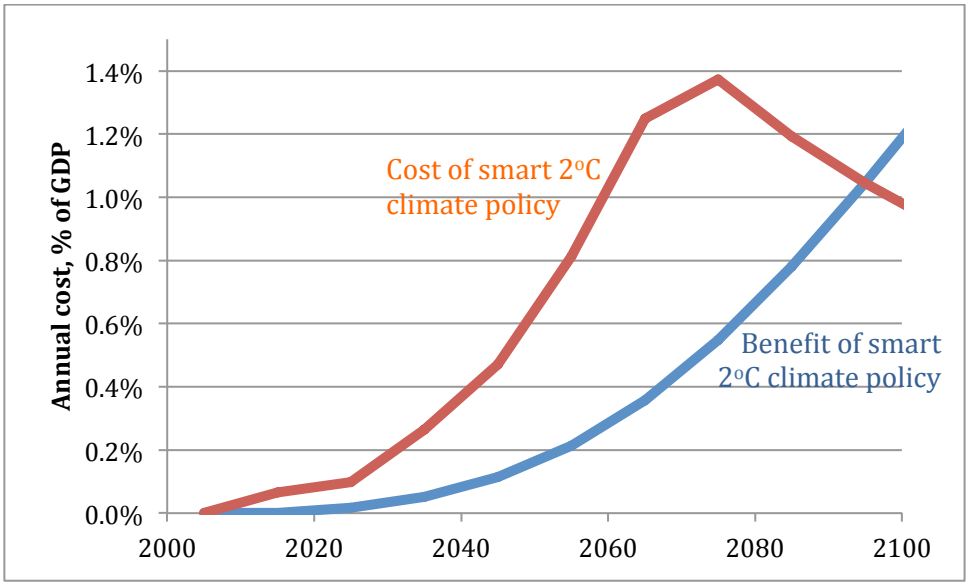


Figure 6 US cost and benefit for each year, in % of US GDP that year of 2°C efficient climate policy. Blue line shows net benefit (avoided costs) from less global warming. Red line shows extra cost. All calculations from RICE.

The important point to realize here is that the costs to the US fall heavily in the early part of the period whereas the benefits tend to come later. This is a standard finding for all climate models and all climate policies.

Here, the cost to the US economy will run upwards of 1.4% of GDP in the second half of the century or about \$600 billion in annual costs vs. \$250 billion in avoided damages.

Despite everyone else including China and India also implementing similarly expensive climate policies, the US costs will outweigh the benefits for the US

from this global policy until the early 2090s, although the benefits will clearly outweigh the costs in the 22nd century and beyond.

With Nordhaus' discounting this climate policy is actually still seen as socially beneficial, because the benefits from future centuries sufficiently outweigh the net cost in this century. The avoided damages run to almost $7 trillion, whereas the policy costs a bit more than $4 trillion. The numbers are almost similar with a traditional 3% discount rate, but with a 5% discount rate, the total policy costs are more than twice the benefits.

Moreover, it seems unlikely that other countries would enact this sort of policy. The annual costs for China would in 2065 be $863 billion annually, with benefits of just $170 billion.

The 'optimal' climate policy. The optimal policy in the RICE model is estimated as the climate policies coordinated and enacted by all nations starting in 2010 that maximize global economic welfare across the next six centuries.

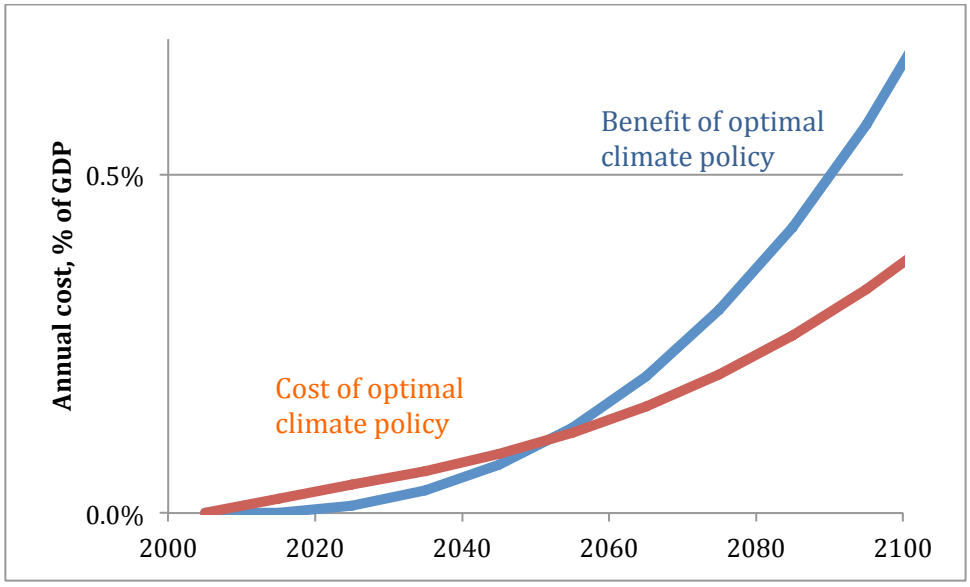


Figure 7 US cost for each year, in % of US GDP that year of optimal climate policy. Blue line shows net benefit (avoided costs) from less global warming. Red line shows extra cost. All calculations from RICE.

The costs and benefits for the US can be seen in Figure 7. Again, the costs outweigh the benefits for the first half-century, but the benefits significantly outweigh the costs for the coming centuries.

This policy is less politically prohibitive, since it requires a lower carbon tax. In the RICE model, the indication is that the global carbon tax would have had to be $9/ton CO_2 in 2010, $12 in 2015 and $16 in 2020, about $50 in 2050 and $130 in 2100.[10] In terms of gasoline, this would have added about ¢8 on a gallon in 2010 globally, ¢18 in 2020, about ¢40 in 2050 and $1.14 in 2100.

This policy is a net benefit, and quite substantial. With Nordhaus' discounting, it costs the world $1.5 trillion, but avoids climate damages worth $5 trillion. With 5% discount rate, it is still a slight net benefit.

Yet, actually seeing this policy enacted is wholly unrealistic, as Nordhaus acknowledges.[11] It requires policies that would be coordinated across the entire world, with carbon taxes imposed even on the poorest nations. For instance, the costs for China would remain higher than the Chinese benefits until after 2080, making this a very hard political sell.

As Nordhaus points out, the costs up till mid-century are five times higher than the benefits:

> Abatement costs are more than five times the averted damages. For the period after 2055… however, the ratio is reversed: Damages averted are more than four times abatement costs. Asking present generations—which are, in most projections, less well off than future generations—to shoulder large abatement costs would be asking for a level of political maturity that is rarely observed.

Importantly, the optimal policy will avoid very little of global warming impacts in the 21st century. Figure 8 shows the total damages for both action and inaction. The damages for inaction (business-as-usual) is just the climate damage from Figure 4, with a cost of about 0.14% of GDP now, and a cost of 1.8% of GDP in 2100. The cost of the optimal, globally coordinated climate policy is the cost of climate policies and the residual negative climate impact. It starts out slightly higher at a cost of 0.16% of GDP now and with a cost of 1.4% of GDP in 2100.

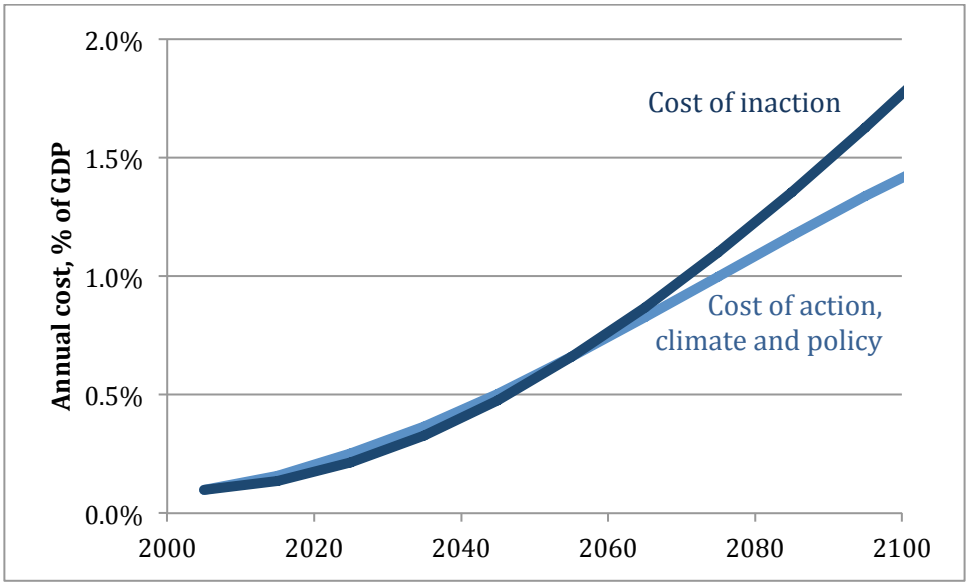


Figure 8 Total cost of climate impact and climate policy for the US. Dark blue line shows the total cost of inaction. Light blue line shows the total cost of smartest, globally coordinated action, both from policy and residual climate damage. All calculations from RICE.

Remembering this is a wholly unrealistic policy to be implemented and be implemented well, the most optimistic statement that can be made on the cost of action and inaction on climate change for the US in the 21st century is that there is little difference. Starting out more expensively, even the optimal climate policy will incur nearly as much cost as no action at all, at 1.4% instead of 1.8% of GDP by the end of the century. As will be apparent below, this is an extremely and unrealistically rosy assessment.

Mostly rich world, ambitious reductions. Both India and China have defended their right to keep their emissions increasing. It is unlikely that they or the rest of the developing, mostly very poor countries will substantially reduce their emissions anytime soon. Nordhaus develops a scenario with rich countries (US, EU, Japan, Russia and the the rest of the rich countries) engage in strong emissions reductions but where the developing countries only participate in the 22nd century.[12] On the current set of policies from both rich and poor countries, this scenario seems a lot more realistic.

In this scenario, the costs are greater than the optimal policy for the rich countries, because they have offered to cut much, much more. This is evident in the EUs professed approach to cut emissions at least 80% below 1990 levels by 2050, and in similar statements from the current US administration.

The benefits, however, are smaller, because many of the biggest emitters are not included. This is readily evident in Figure 9, where China now emits almost twice what the second-largest emitter, the US, does. Of course, China, India and the other poor country emitters will still experience a net benefit in lower climate damages due to the generous reductions from the rich countries.

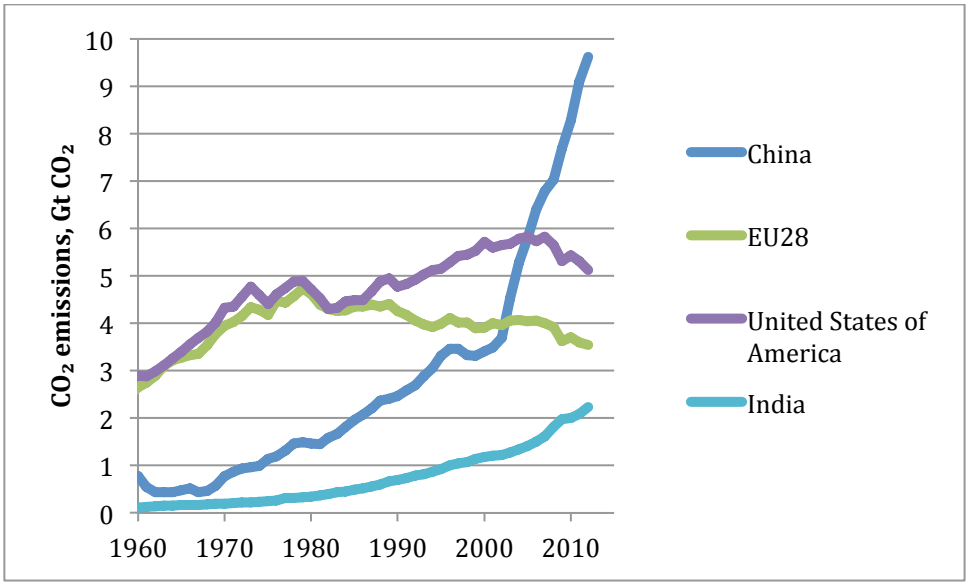


Figure 9 CO_2 emissions from the leading four emitters, China, US, EU and India, 1960-2012.[13]

Nordhaus estimate the future US reductions from the 2009 US climate bill that was passed by the House but not the Senate. In this scenario, the US will by mid-century have reduced its emissions some 75% below what they would otherwise have been.

The climate policy costs for the US will not be trivial. Assuming a full trading zone between all participants, the annual policy costs will run to $145 billion by mid-century and some $250 billion by the end of the century, or about 0.4% of GDP. The full trading assumption is rather unrealistic, as trading has generally been only weakly implemented and often only for small parts of the emissions spectrum. The more realistic cost with a no-trade assumption shows the US costs at about twice the annual cost at $280 billion by mid-century and $400 billion by the end of the century.

We can check the reasonableness of these costs by looking at the well-modeled costs of the EU climate policy to 2020.[14] The average cost by 2020 from 6 models runs to €209 billion or about $280 billion per year (1.3% of GDP). The Nordhaus model (admittedly doing a much more simplified analysis) finds the cost at less than $5 billion, even without trade, suggesting that the RICE estimates are certainly not exaggerated.

However, a consistent result from the studies of the EU climate policy is that real climate policies are often poor, second-best policies, with a mish-mash of regulation of different sectors and regions. The most pertinent summary of the Stanford Energy Modeling Forum's assessment of the EU policies finds:

> Second-best policies increase costs. A policy with two carbon prices (one for the ETS, one for the non-ETS) could increase costs by up to 50%. A policy with 28 carbon prices (one for the ETS, one each for each Member State) could increase costs by another 40%. The renewables standard could raise the costs of emissions reduction by 90%. Overall, the inef!ciencies in policy lead to a cost that is 100–125% too high.[15]

Thus, it is very likely that a more realistic estimate of costs will be a bit above twice the optimal estimate. For the RICE model, that means that the US costs of an ambitious climate policy will more likely incur annual costs of about half a trillion by mid-century and some $800 billion by the end of the century.

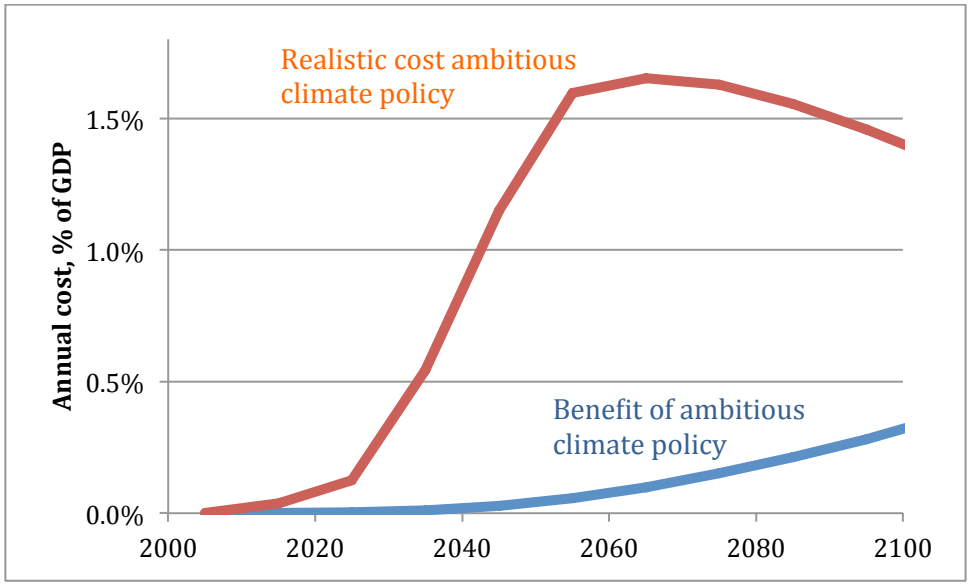


Figure 10 US cost and benefits for each year, in % of US GDP that year of realistic, ambitious climate policy ("Copenhagen Accord with only rich countries," no trade and 2x policy costs). Blue line shows net benefit (avoided costs) from less global warming. Red line shows policy costs. All calculations from RICE.

The overview of the 21st century is available in Figure 10. The policy cost is vastly greater than the avoided climate damages, with costs running above 1.5% of GDP (about similar to what the moderate EU climate efforts will cost the EU by 2020), while benefits run between 0.1% and 0.3% in the second half of the century.

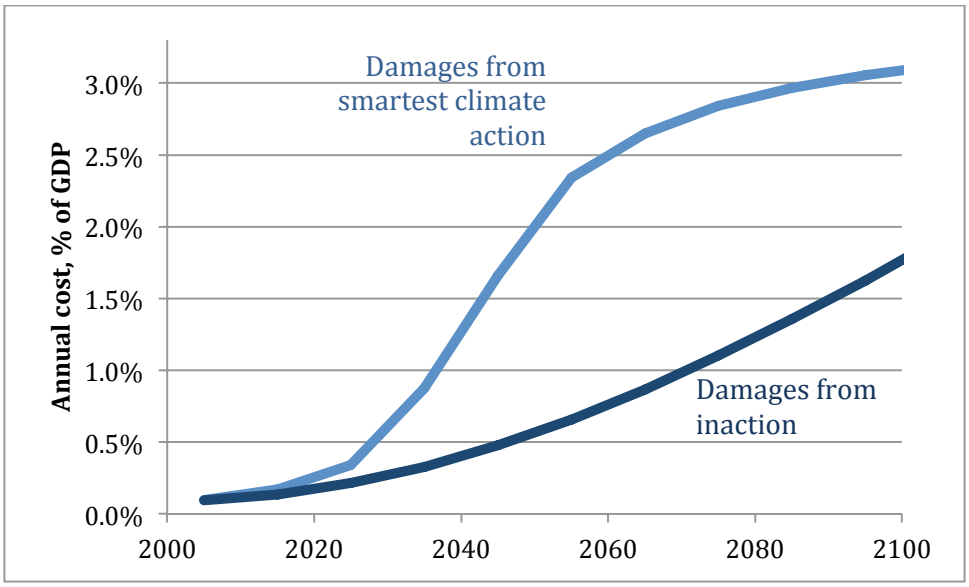


Figure 11 Total damages from climate impact and climate policy costs for the US, in % of US GDP that year. Dark blue line shows the total cost of inaction. Light blue line shows the total cost of realistic, ambitious climate action. All calculations from RICE.

Again, it is important to emphasize that such an ambitious climate policy does not reduce total impacts to the US economy or the federal budget, but actually dramatically increase the total cost, as is evident in Figure 11. In such a situation the US would have to both suffer significant costs from only slightly reduced climate change while incurring even higher policy costs.

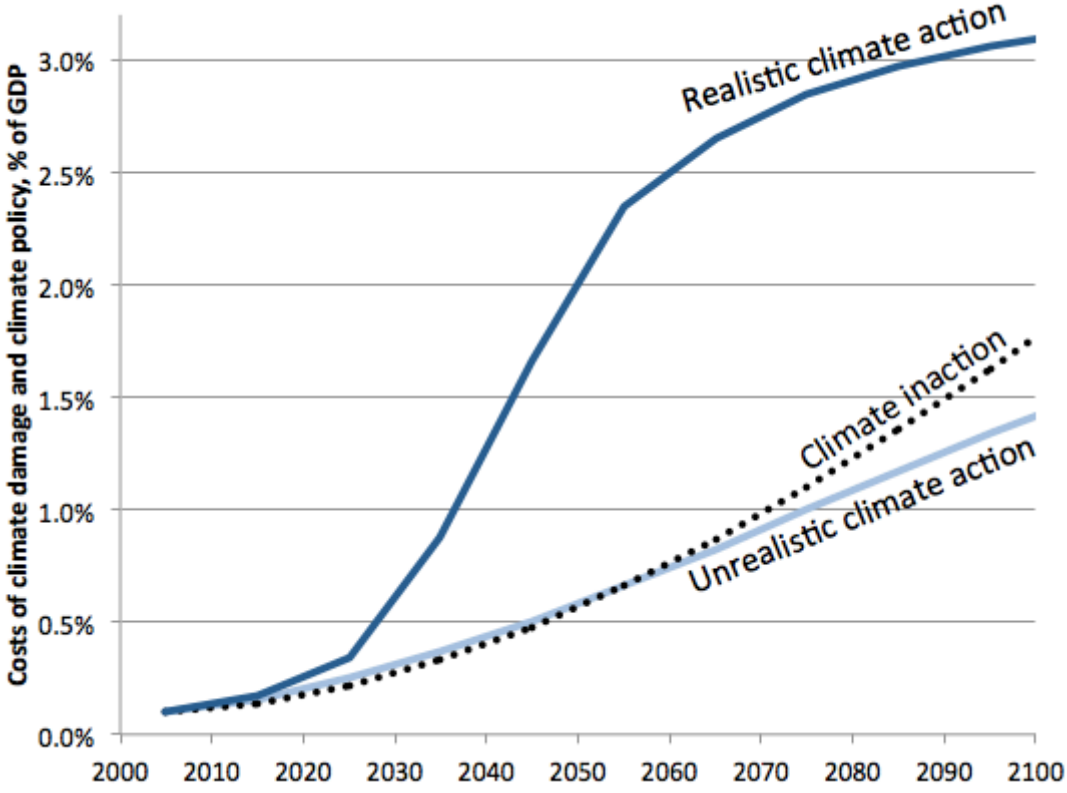


Figure 12 Total costs and benefits from inaction and action for the US. Black dotted line shows the cost of inaction. The light blue line shows the absolutely best-case cost of optimal, globally coordinated policies, with the cost of policy and the cost of residual climate damage. Dark blue line

shows the more realistic cost of a mostly rich-country-led, ambitious, second-best climate policy along with residual climate damage. All calculations from RICE.

Figure 12 answers the committee's question on the costs of unchecked climate change – but compares it with the cost of different climate policies. The costs of inaction rise through the century to about 1.8% of GDP in 2100. With extremely unrealistically optimistic assumptions, it is possible that the total cost of climate policy action will be reduced *slightly* to 1.5% of GDP by the end of the century. With more likely assumptions, the cost of climate action will end up costing upwards of twice as much as climate inaction in this century, or about 3.1% of GDP towards the end of the century. No matter what, the cost of action is higher than the cost of inaction in the first half of the century.

Another way to see look at the cost of action and inaction is to look at the total, discounted cost of global warming and global warming policy on the 21st century in Figure 13. The cost for the unrealistic action, the optimal policy, is 0.49% of the period's total GDP. The cost for inaction is 0.52%, while the cost for the optimal 2°C policy is 0.78% and the realistic, ambitious climate policy is 1.17%. For following centuries, the relative cost of inaction will increase.

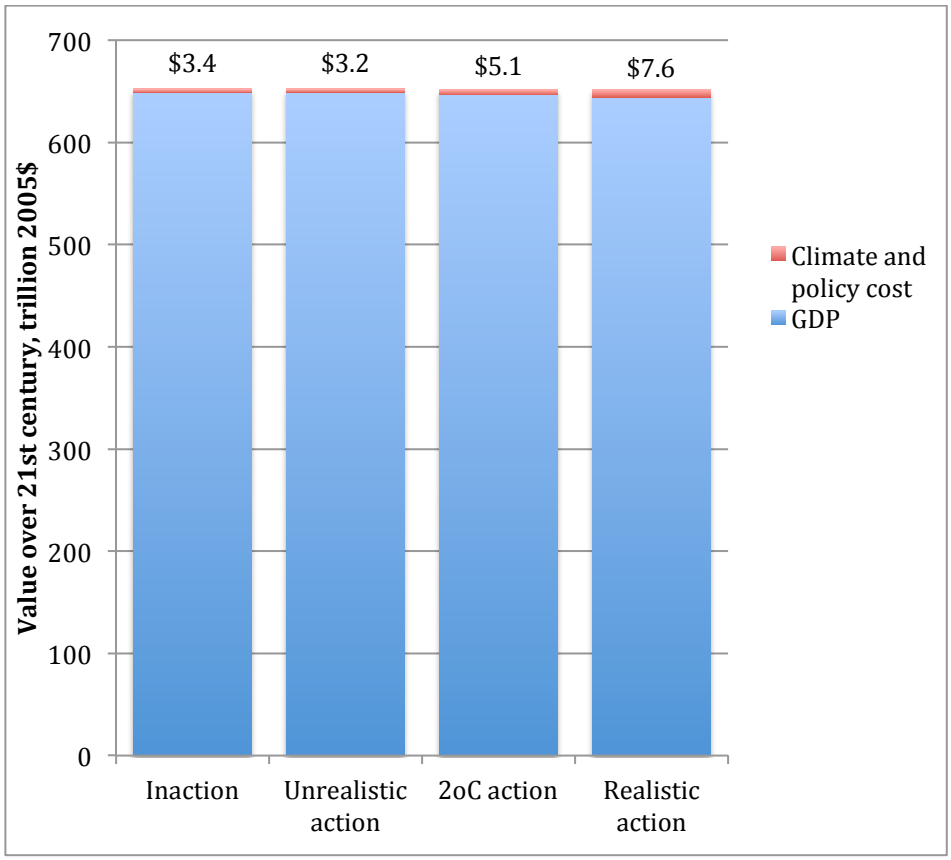


Figure 13 Costs of climate impacts and climate policy, and remaining GDP, for four different scenarios, over 21st century. The unrealistic action is the optimal action, generating a climate and policy cost of $3.2 trillion, and with a remaining GDP of $649.1 trillion. Realistic action is the mostly-rich-world scenario All calculations from RICE.

Two points are clear. First, global warming is by no means the most important part of the 21st century. Second, there is much greater scope for climate policies to make the total climate cost *greater* thought the 21st century.

Unchecked climate is catastrophic: hurricanes

Secretary of State John Kerry said of the latest Intergovernmental Panel on Climate Change (IPCC) report that "the costs of inaction are catastrophic."[16] This is a standard comment on global warming, though it is simply not well founded, as we have seen above in Figure 13. Often claims of more weather extremes are invoked[17], although such arguments generally do not hold true. [18]

The IPCC special report on extreme weather found[19]:

- "There is high confidence, based on high agreement and medium evidence, that economic losses from weather- and climate-related disasters have increased"
- "There is medium evidence and high agreement that long-term trends in normalized losses have not been attributed to natural or anthropogenic climate change"
- "The statement about the absence of trends in impacts attributable to natural or anthropogenic climate change holds for tropical and extratropical [winter] storms and tornadoes"
- "The absence of an attributable climate change signal in losses also holds for flood losses."

These findings are also reflected in the recent literature, e.g.: "In general we find no significant upward trends in normalized disaster damage over the period 1980–2009 globally, regionally, for specific disasters or for specific disasters in specific regions."[20] The most recent scientific paper found the same: "The absence of trends in normalized disaster burden indicators appears to be largely consistent with the absence of trends in extreme weather events."[21]

Take a look at the often claimed increase in hurricanes, which constituted a significant part of Al Gore's claims in his book and movie. This was also the argument made with superstorm Sandy.

Yet, as is evident in Figure 14, the number of landfalling US hurricanes have *not* increased, but possibly slightly decreased. Certainly, the normalized damage from US hurricanes has not increased.[22] Although costs have gone up, this is due entirely to more people with more assets to be harmed.

It is instructive to look at the long-term impact of global warming on hurricanes. The global warming models do not agree even on whether hurricanes get stronger or weaker for most basins.[23] Yet, a prominent recent analysis indicated that the strongest increase in hurricane power would take place over North America.[24] It finds that the annual average, current hurricane damage is at about 0.1% of US GDP at $17 billion. By 2100, social changes with more people and more assets will increase the annual hurricane damage to about $28 billion, but given that the US GDP will have increased 7-fold, the percentage damage will be about 0.02%. Because of the projected increase in hurricane power in the North Atlantic, caused by global warming, they estimate that the damages will increase another $26 billion, to a total of $54 billion per year in 2100. Yet, this will still make up less than 0.05% of GDP losses in 2100. And so, even assuming that hurricanes will get much stronger from global warming, the overall impact will not be increasing, but actually halve from 0.1% to 0.05% of GDP.

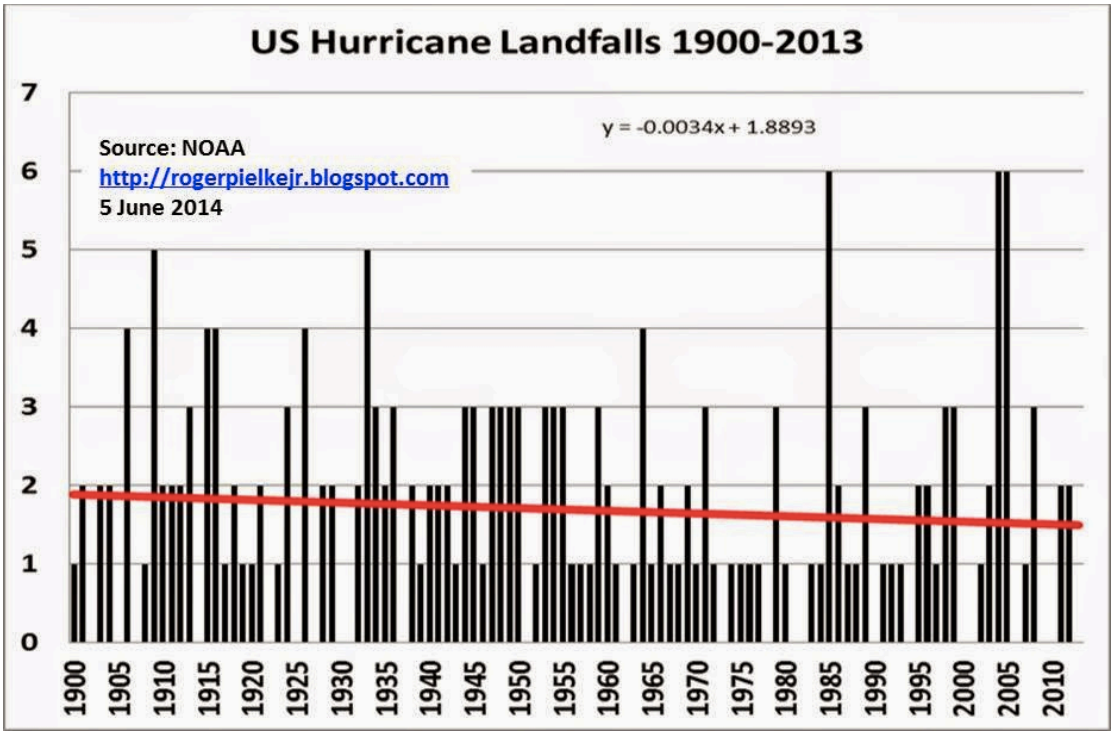


Figure 14 Number of US landfalling hurricanes, 1900-2013.[25]

Failed policies to tackle global warming

This underscores the central question of how else to approach global warming.

The first realization needs to be that the current, old-fashioned approach to tackling global warming has failed. 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 $280bn/year.[26]

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).[27]

Third, **green energy is not ready** to take over from fossil fuels.[28] 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)[29], and because it

typically produces electricity, which is not generated with oil, it doesn't reduce oil dependence[30]. 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%.[31]

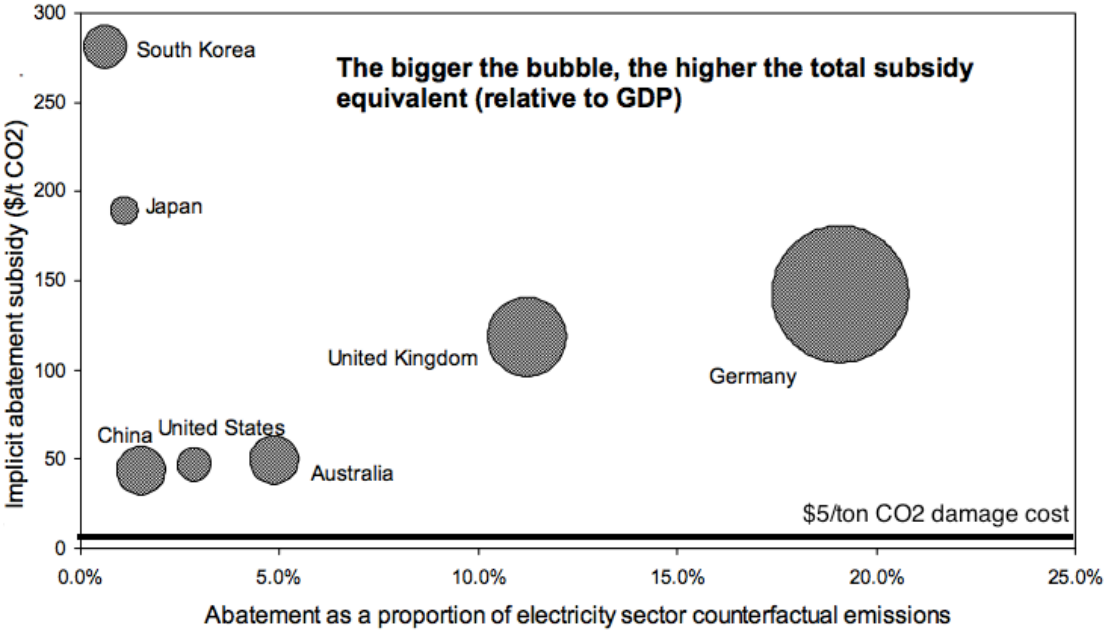


Figure 15 Abatement and implicit CO2 reduction cost for electricity, various nations. $5/ton CO2 damage insert for referece. In AUS$, which is almost equivalent to US$.[32]

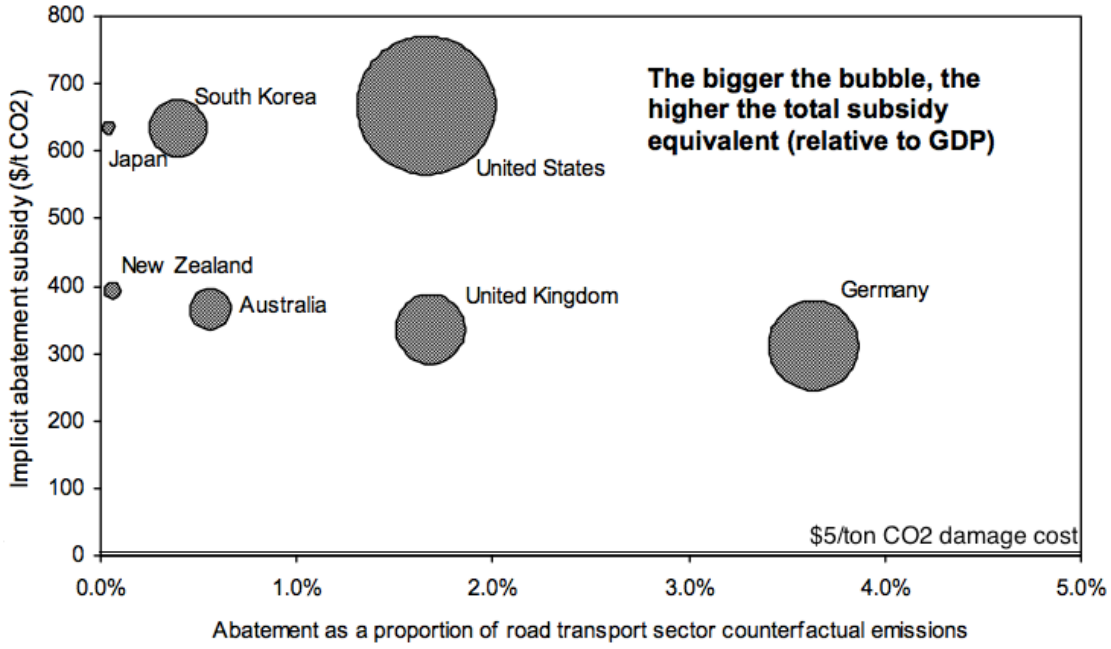


Figure 16 Abatement and implicit CO2 reduction cost for biofuels, various nations. $5/ton CO2 damage insert for referece. In AUS$, which is almost equivalent to US$.[33]

Because there is no good, cheap green energy, the almost universal political choices have been expensive policies that do very little. In Figure 15 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,[34] 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 16. 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.

Failed policies to tackle global warming

It is often emphasized how global warming will eventually harm the world's poor the most. In the words of UN General-Secretary Ban Ki-Moon, "Climate change harms the poor first and worst."[35] It will harm the poor because they are the most vulnerable and have the least resources to adapt.

But this neglects the other climate impact: Current global warming *policies* make energy much more costly. This negative impact is often much larger, harms the world's poor much more, and is much more immediate.

Solar and wind power was subsidized by $60 billion in 2012,[36] despite their paltry climate benefit of $1.4 billion.[37] Essentially, $58.6 billion were wasted. Depending on political viewpoint, that money could have been used to get better health care, more teachers, better roads, or lower taxes. Moreover, forcing everyone to buy more expensive, less reliable energy pushes higher costs throughout the economy, leaving less for welfare.

The burdens from these climate policies fall overwhelmingly on the world's poor. This is because rich people can easily afford to pay more for their energy, whereas the poor will be struggling. It is surprising to hear that well-meaning and economically comfortable greens often suggest that gasoline prices should be doubled or electricity exclusively sourced from high-cost green sources.

This is easy to say for residents of affluent Hunterdon County in New Jersey who according to the New York Times are so rich, they spend just 2 percent of their income on gasoline.[38] Yet, the poorest 30 percent of the US spend almost 17% of their after-tax income on gasoline.[39] Josephine Cage from Mississippi has to drive to her fish fillet job four days a week, spending $200 a month on gas, nearly 20 percent of her pay. [40] She already replaces meat at supper with soups and green beans and broccoli, and she just fills her car a little bit every day, because "I can't afford to fill it up." Doubling her gasoline cost isn't a cavalier gesture.

In the UK, environmentalists proudly announce that households have reduced their electricity consumption by almost 10% since 2005.[41] They fail to mention this is because of a 50% increase in electricity prices[42] in part to pay for the UK increasing its share of renewables from 1.8% to 4.6%. Such a price increase

disproportionately harms the poor. As many environmental taxes, it is regressive because it taxes a basic necessity that makes up a larger proportion of a small budget.[43] Not surprisingly, the poor have had to reduce their electricity consumption far more than the richest segment, who haven't reduced their electricity consumption at all.[44]

Over the past five years, heating a home in the UK has become 63% more expensive[45], while real wages have declined.[46] Unsurprisingly, a greater number of poor households must spend more than 10% of their income on energy, becoming what is known as *energy poor*.[47] More than 17% of all British households are now energy poor.[48] Worse, because the elderly are typically poorer, energy poverty affects about a quarter of all households above 60 years of age.[49] Deprived pensioners are spending their days riding heated busses[50] or burning old books to keep warm[51], while a third are leaving part of their homes cold.[52]

Widow Rita Young, 75, explains simply: "I've worked all my life. It doesn't feel fair. People my age don't want to put hats and scarves on in their homes, but there's nothing we can do about it. I sit in a blanket, put on a hat and sometimes go to bed at 7.30 in the evening."[53] She joins almost a million other pensioners, who are forced to stay in bed longer to keep warm because of rising fuel bills.[54]

But things could be worse. In Germany green subsidies will cost €23.6 billion this year. Real household electricity prices have increased 80 percent since 2000, as is evident in Figure 17. This has contributed to the almost seven million households now living in energy poverty. A fourth of all consumer electricity costs are now direct subsidies to renewables. Wealthy homeowners in Bavaria might feel good about installing inefficient solar panels on their roofs, but their lavish subsidies are essentially financed by poor tenants in the Ruhr paying higher electricity costs.

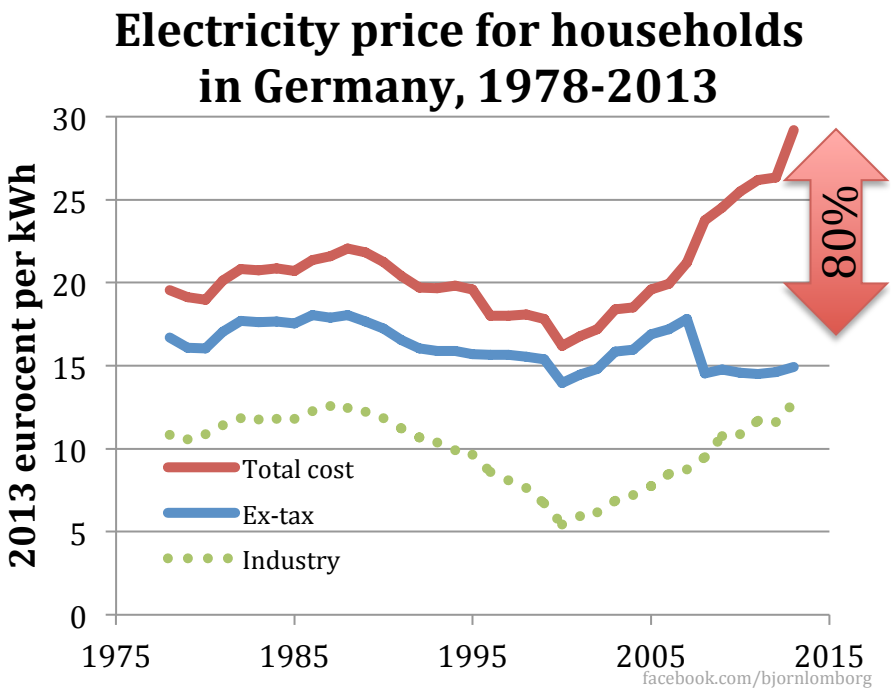


Figure 17 Electricity price for households in Germany, 1978-2013.[55]

Climate policies carry an even larger cost on people in the developing world. Almost 3 billion people rely on burning twigs and dung to cook and keep warm. This causes indoor air pollution at the cost of 4.3 million lives per year, and creates the world's biggest environmental problem. Access to cheap and plentiful electricity is one of the most effective way out of poverty. It curtails indoor air pollution and allows refrigeration to keep food from spoiling. It charges computers that connect the poor to the world. It powers agriculture and businesses that provide jobs and economic growth.

Take Pakistan and South Africa. With too little generating power both nations experience recurrent blackouts that cost jobs and wreck the economy. Muhammad Ashraf, who worked 30 years at a textile plant in central Pakistan, was laid off last year because of these energy shortages.[56] Being too old to get another job, he has returned to his village to eke out a living growing wheat on a tiny plot of land. Instead of $120 a month, he now makes just $25.

Yet, the funding of new coal fired power plants in both Pakistan and South Africa has been widely opposed by well-meaning Westerners and climate-concerned Western governments.[57] They instead urge these countries to get more energy from renewables.

But this is cruelly hypocritical. The rich world generates just 0.76% of its energy from solar and wind, far from meeting even minimal demand. In fact, Germany will build ten new coal-fired power plants over the next two years to keep its own lights on.

Africa is the renewable utopia, getting 50% of its energy from renewables – though nobody wants to emulate it. China used to derive 40% of its energy from

renewables in 1971. Since then, it has powered its incredible growth almost exclusively on heavily polluting coal, lifting an historic 680 million people out of poverty. Today, China gets a trifling 0.23% of its energy from unreliable wind and solar.

Yet, most Westerners still want to focus on putting up more inefficient solar panels in the developing world. But this infatuation has a real cost. A recent analysis from the Center for Global Development shows that $10 billion invested in renewables will help lift 20 million people in Africa out of poverty.[58]

But the same $10 billion spent on gas electrification will lift 90 million people out of poverty. , $10 billion can help just 20 million people. Using renewables, we deliberately end up choosing to leave more than 70 million people – more than 3 out of 4 – in darkness and poverty.

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[59]. 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.[60] 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 about 40% coal and 30% gas.

This means that the US has reduced its annual CO_2 emissions by about 300Mt CO_2 in 2012.[61] 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. At the same time, the EU climate policy will cost about $280 billion per year, whereas the US fracking is estimated to *increase* US GDP by $283 billion per year.

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[5] p19, http://ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf
[6] Calculated from Nordhaus RICE model 2010, http://nordhaus.econ.yale.edu/RICEmodels.htm
[7] Data from Worldbank Global Development Indicators, http://databank.worldbank.org/data/views/variableSelection/selectvariables.aspx?source=world-development-indicators.
[8] Nordhaus 2010, p4, recalculated to per ton CO_2 and CPI corrected to 2013.
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[10] Nordhaus 2010, p4, recalculated to per ton CO_2 and CPI corrected to 2013.
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"Examining the Threats Posed by Climate Change"

Testimony by
Raymond J. Keating
Chief Economist
Small Business & Entrepreneurship Council

July 29, 2014

Before the
Committee on Environment and Public Works

Subcommittee on Clean Air and Nuclear Safety

United States Senate

The Honorable Sheldon Whitehouse, Chairman
The Honorable Jeff Sessions, Ranking Member

Chairman Whitehouse, Ranking Member Sessions, and Members of the Committee, thank you for hosting this hearing today on the impact of climate change on communities and the economy. My focus is going to be on the negative effects that regulations tied to the issue of climate change have on small businesses and the economy.

I am pleased to submit this testimony on the behalf of the Small Business & Entrepreneurship Council (SBE Council) and our Center for Regulatory Solutions.

My name is Raymond Keating, and I am the chief economist for SBE Council, as well as serving as an adjunct professor in the Townsend Business School at Dowling College where I teach a variety of courses in the MBA program; a weekly newspaper columnist for *Long Island Business News*; and author of several books, with the latest nonfiction book being *Unleashing Small Business Through IP: Protecting Intellectual Property, Driving Entrepreneurship*.

SBE Council is a nonpartisan, nonprofit advocacy, research and training organization dedicated to protecting small business and promoting entrepreneurship. With nearly 100,000 members and 250,000 small business activists nationwide, SBE Council is engaged at the local, state, federal and international levels where we collaborate with elected officials, policy experts and business leaders on initiatives and policies that enhance competitiveness and improve the environment for business start-up and growth. The Center for Regulatory Solutions is a project of SBE Council.

The State of the Economy

Of course, the state of the economy must be weighed heavily when considering any major policy endeavor, including, of course, significant regulatory measures. After all, the economics of regulation is rather straightforward, that is, regulations raise the costs of and create uncertainties for investment, business and entrepreneurship, thereby restraining critical risk taking, along with productivity, economic growth and job creation. In turn, the wages and incomes of workers and families suffer.

While I would argue that, especially given the current burdens imposed by government, it's never a good time to impose significant regulatory or tax burdens on entrepreneurs, businesses, investors and workers, the current period is a particularly troubling time given how poorly the U.S. economy has performed in recent years, and how poorly it continues to perform.

Consider some facts about recent U.S. economic performance:

• The U.S. has not achieved respectable levels of annual real economic growth since 2004 and 2005 (3.8 percent and 3.4 percent growth, respectively), that is, about a decade ago.

• In fact, it can be argued that the U.S. has experienced a lost 13-plus years when it comes to economic growth. From 1950 to 2000, real annual GDP growth averaged 3.7 percent. That compares to average annual growth of only 1.8 percent from 2001 to 2013. Why does this matter? Well, one way of thinking about it is that at 3.7 percent growth, real GDP doubles every 18.9 years, while at 1.8 percent real GDP doubles every 38.9 years. Quite simply, the improvement in our standard of living has suffered dramatically in recent years.

• From 2007 to 2013, annual real GDP growth averaged a woeful 1.0 percent. Keep that up, and real GDP doubles every 70 years.

• Consider that from 1983 to 2000, an 18-year period, the U.S. had one recession. During the 13 years from 2001 to 2013, the U.S. had two recessions – the latest being one of the worst since the Great Depression.

• During this recovery (which began in mid-2009), real GDP growth has averaged only 2.1 percent. That compares to a 4.5 percent average rate experienced during recovery/growth periods since 1950.

• And of course, real GDP actually shrank by 2.9 percent in the first quarter of 2014. That's a stunning contraction in the economy, by far the worst performance since the first quarter of 2009, during the depths of the last recession. In addition, consider that first quarter GDP included a decline of 11.7 percent in real gross private domestic investment (with intellectual property investment being the only major subsection with growth at 6.3 percent). That was the worst performance since the second quarter of 2009. In addition, real exports declined by 8.9 percent. Again, that was the poorest number since the first quarter of 2009.

• Lackluster private investment stands out as the most troubling issue in this very troubling economy, given that private investment is vital for economic growth now and in the future. As of 2013, real gross private domestic investment still had not recovered to the recent high hit back in 2007. In fact, real private investment in 2013 was still down by 6 percent compared to 2007. That's the worst performance, by far, since the Great Depression.

• Productivity growth has lagged recently as well. Labor productivity grew at a mere 0.4 percent in 2011, 1.4 percent in 2012, and 0.9 percent in 2013. That compared to a post-World War II average of 2.5 percent, and an average since 1980 of 2.1 percent. During the first quarter of 2014, productivity actually dropped by 3.5 percent. And keep in mind the link between productivity and capital investment. That is, when businesses make capital investment, that in turn boosts labor productivity. Quite simply, workers have improved tools and technology with which to work, and increased productivity leads to increased income. In fact, the reason that Americans earn among the highest incomes around the world is because they rank among the most productive.

Given this poor economic performance, the question is: Why? That is, why has the U.S. been suffering through such tough economic times? It's overwhelmingly about policy. Unfortunately, each major area of public policy has been pointed in anti-growth direction. Consider the following:

• Federal government spending as a share of GDP exploded from 2000 to 2009, and has remained at elevated levels ever since – thereby draining large amounts of resources from the private sector.

• Tax policy has been aggressively anti-entrepreneur, anti-investment, and anti-growth since 2009, serving as a real impediment to risk taking.

• After declining in the 1980s, regulatory costs have been mounting ever higher since, with recent years amounting to hyper-activity on the regulatory front (more on regulation below).

• For the past nearly six years, the U.S. largely has been absent from its traditional global leadership role in advancing free trade (though that may be changing with recent efforts regarding the Transatlantic Trade and Investment Partnership (TTIP) and the Trans-Pacific Partnership (TPP)).

• And finally, the Federal Reserve has created enormous uncertainty by running the loosest monetary policy in the history of the nation over the past six years.

This is the worst possible economic scenario to be imposing or considering an additional, massive regulatory intrusion into the economy in the name of climate change, or in the name of anything else, for that matter.

The Real Economic Challenge: Costs of Government Action

Indeed, from an economics perspective, when it comes to the climate change regulatory agenda, the only outcome that we can be confident in is that new regulatory and/or tax regimes will impose very real costs on and reduce economic efficiency in industries, businesses, and the economy—all without providing any meaningful climate benefits or reductions in global temperatures. In other words, all pain for no gain.

When focusing on the threats posed and costs imposed by climate change, the clearest and most significant come from the resulting government actions, in particular, increased regulatory and tax burdens, such as mandating reductions in carbon-dioxide emissions, mandating the use of costly and inefficient alternative sources of energy, and/or imposing some kind of carbon tax.

The implications of a carbon tax are the clearest. That is, a tax is imposed in order to raise the cost of carbon-based energy. That's what Australia did in 2010. But earlier this month, Australia repealed the levy. A *Wall Street Journal* editorial ("Australia's Carbon Tax Message," July 17, 2014) noted that the tax was imposed at "A$23 (US$21.54) per ton of carbon," and "The government's own figures estimate the tax added A$9.90 to the average household's weekly power bill. The burden to industry has been even greater, exacerbating Australia's loss of competitiveness in manufacturing. The tax was due to increase to A$25.40 on July 1, and then become a cap-and-trade scheme in 2015."

The costs of taxes tend to be far more transparent and obvious to the public than is the case with regulations. Hence, higher taxes tend to be unpopular with voters. That was the case with Australia's carbon tax, and now it has been repealed.

Given how unpopular taxes are, elected officials often will turn to imposing regulations. While the costs of regulations are just as real as taxes, they remain largely hidden from the eyes of

consumers and voters. Businesses are largely left to deal with the costs of regulation. Therefore, it is easier to regulate than to tax from a political perspective.

But while the costs of regulation amount to a "hidden tax," the economics of regulation are clear. Economics 101 tells us what to expect from increased regulation – that is, higher costs for businesses and consumers, reduced market exchanges and expanded political control, resources allocated based on political dictates and influences (such as rent seeking) rather than via competition and consumer sovereignty, and therefore, diminished economic growth.

Consider various findings on the costs of regulation over the years:

• Economists John Dawson at Appalachian State University and John Seater at North Carolina State University recently looked at the impact of federal regulation on economic growth ("Federal Regulation and Aggregate Economic Growth," January 2013), and offered some noteworthy findings. They reported: "Regulation's overall effect on output's growth rate is negative and substantial. Federal regulations added over the past fifty years have reduced real output growth by about two percentage points on average over the period 1949-2005. That reduction in the growth rate has led to an accumulated reduction in GDP of about $38.8 trillion as of the end of 2011. That is, GDP at the end of 2011 would have been $53.9 trillion instead of $15.1 trillion if regulation had remained at its 1949 level."

• As reported in "Ten Thousand Commandments: An Annual Snapshot of the Federal Regulatory State" (2014 Edition published by the Competitive Enterprise Institute) by Clyde Wayne Crews Jr.:

- "The estimated cost of regulation exceeds half the level of the federal budget itself. Regulatory costs of $1.863 trillion amount to 11.1 percent of the U.S. gross domestic product (GDP), which was estimated at $16.797 trillion in 2013 by the Bureau of Economic Analysis."

- "When regulatory costs are combined with federal FY 2013 outlays of $3.454 trillion, the federal government's share of the entire economy now reaches 31 percent."

- "The regulatory 'hidden tax' surpasses the income tax. Regulatory compliance costs exceed the 2013 estimated total individual income tax revenues of $1.234 trillion."

- "Regulatory compliance costs vastly exceed the 2013 estimated corporate income tax revenues of $288 billion and approach corporate pretax profits of $2.19 trillion."

- "U.S. households 'pay' $14,974 annually in regulatory hidden tax, thereby 'absorbing' 23 percent of the average in- come of $65,596, and 'pay' 29 percent of the expenditure budget of $51,442. The 'tax' exceeds every item in the budget except housing. More is 'spent' on embedded regulation than on health care, food, transportation, entertainment, apparel and services, and savings."

• In a May 2014 study for the Mercatus Center ("Regulation and Productivity"), Antony Davies, an associate economic professor at Duquesne University and a senior scholar at George Mason University, reported: "Over the period 1997 through 2010, the 221 least-regulated industries in each year averaged 3.5 percent annual growth in output per hour in the subsequent year while the 221 most regulated industries averaged a significantly lower 1.9 percent annual growth. Accumulating the growth rates over all the years, the least regulated industries experienced a total of 64 percent growth in output per hour from 1997 through 2010 versus 34 percent for the most-regulated industries… Over the period 1997 through 2010, the least regulated industries in each year averaged 3.4 percent annual growth in output per person in the subsequent year while the most regulated industries averaged 1.8 percent annual growth. Accumulating the growth rates over all the years, the least regulated industries experienced 63 percent growth in output per person versus 33 percent growth for the most regulated industries."

• In a July 1996 study ("Federal Regulation's Impact on the Productivity Slowdown: A Trillion-Dollar Drag," Center for the Study of American Business, July 1996), Dr. Richard Vedder estimated that rising regulations between 1963 and 1993 explained almost half of the nation's slowdown in long-run productivity over that period, that is, annual productivity growth would have been 1 percentage point higher if regulations had remained at 1963 levels.

The Impact of Regulations on Small Business

Considering these enormous costs, let's zero in on a critical sector of the economy, that is, small business.

The Small Business Administration's Office of Advocacy periodically estimates regulatory costs, obviously with an eye towards the burdens imposed on smaller businesses. In September 2010, the Office of Advocacy published an updated study estimating the costs of complying with federal regulations. The study – "The Impact of Regulatory Costs on Small Firms" by Nicole V. Crain and W. Mark Crain from Lafayette College – provided details regarding the burdens of federal regulatory costs. For example:

• For firms with less 20 employees, the per-employee cost registered $10,585, which was 42% higher than the $7,454 per employee cost for firms with 20-499 employees, and 36% higher than the $7,755 for firms with 500 or more employees.

• On the environmental front, per employee regulatory costs for firms with less than 20 employees came in at $4,101, which topped the $1,294 cost for firms with 20-499 employees by 217% and the $883 cost for businesses with 500 or more workers by 364%.

• Small manufacturers get hit particularly hard. Per employee regulatory costs for manufacturers with fewer than 20 employees came in at $28,316, which was 110% higher than the $13,504 for manufacturers with 20-499 employees and 125% more than the $12,586 burden on companies with 500 or more employees. Again, serious cost differentials came in the area of environmental regulation, where per employee costs for manufacturers with fewer than 20 employees came in at $22,594, which topped the $7,131 for firms with 20-499 employees by 217% and exceeded the $4,865 for firms with 500 or more workers by 364%.

The burden of regulation on small business is significant and disproportionate. Unfortunately, that economic reality seems to go unnoticed by too many elected officials.

Piling More Regulation on Small Business

No matter the state of the economy and the costs of regulation, including on small business, various players in the federal government push to impose additional regulations in the name of climate change. For example, there's been a great deal of talk about the Environmental Protection Agency (EPA) and a "war on coal."

In 2013, the EPA proposed regulations imposing strict carbon dioxide emission limits on any new power plants built in the U.S. Specifically, the limits make it exceedingly difficult to build a new coal-fired plant. When the proposal was released last year, Hal Quinn, president and CEO of the National Mining Association, pointed out, "The rule effectively bans construction of the most efficient power plants the nation will need to provide affordable electricity for a growing economy and will certainly create further economic hardships for millions of families, especially those most vulnerable to higher energy costs." As reported by *USA Today* on September 9, 2013 ("EPA proposes strict emission limits on new power plants"), while the limits would force new plants to limit CO2 emissions to 1,100 pounds per megawatt-hour of power produced, existing coal plants run in the range of 1,600 to 2,100 pounds. For good measure, there is the problem that the technology required to meet the standards, as widely reported, has never been used on a commercial level.

And in June of this year, the EPA came forward with emission limits on existing power plants, which will force a 30 percent reduction in carbon emissions from existing power plants from 2005 levels by 2030.

In reality, this is not just a "war on coal," but also a "war on small business."

For example, consider key ways that small businesses would be damaged under the emissions regulations on existing power plants:

• First, EPA regulation promises to inflict sizeable costs and damage on the economy. Straightforward economics makes clear that whatever the details of the regulatory schemes used by the states or imposed by the EPA – such as a carbon tax, cap-and-trade regulations, forcing greater utilization of non-economic renewables like wind and solar, and/or political rationing or management of electricity usage (i.e., dictating how and when consumers and businesses can use electricity) – the costs will be formidable.

For example, the U.S. Chamber of Commerce's Institute for 21st Century Energy recent study titled "Assessing the Impact of Potential New Carbon Regulations in the United States" projected $28.1 billion annually in compliance costs, $17 billion in added electricity costs for consumers annually, $51 billion in real GDP losses annually, $200 in lost real disposable income per household annually, and 224,000 in annual job losses through 2030. By the way, while the Chamber study assumed a slightly more stringent 42 percent reduction in emissions from the

2005 level by 2030, it's clearly far more accurate in terms of the direction and scope of costs compared to the fantasy-like assertions made by the EPA that benefits would far exceed assumed minimal costs.

Notably, EPA has tried mightily to dismiss the Chamber's study, arguing that it was based on a proposal by the Natural Resources Defense Council, *not* on what EPA ultimately proposed in June. But the crux of EPA's existing source rule was taken directly from NRDC's plan. Dallas Burtraw, of Resources for the Future, told the *New York Times* recently: "The NRDC proposal has its fingerprints throughout this, for sure." The Times also reported that NRDC conceived "the novel idea at the heart of Mr. Obama's climate-change rule."

When it comes to climate change regulation, we often hear that such regulation will actually create jobs, or "green jobs," as they were called not too long ago. Whether from installing more efficient technology in homes or constructing wind turbines, new jobs will undoubtedly be created to comply with new climate change regulatory requirements. But this analysis fails to account for the loss of jobs in other sectors of the economy caused by those same requirements. In sum, climate regulation, because it increases energy costs and lowers productivity, will create an *overall net loss of jobs*.

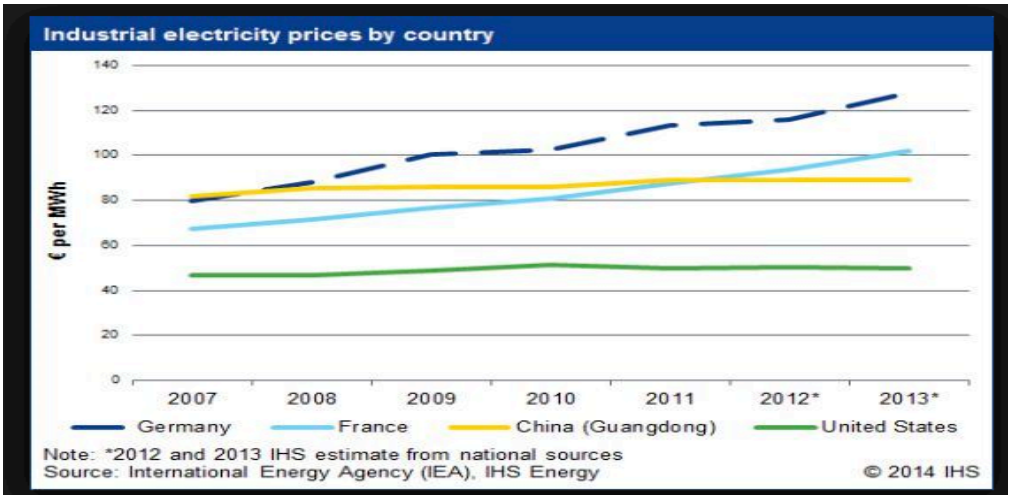
This point was articulated well in a study for the National Black Chamber of Commerce by CRA International, which examined the economic impacts of the Waxman-Markey cap-and-trade legislation. As the authors found:

> "The present study finds that the cap-and-trade program would lead to increases in spending on energy efficiency and renewable energy, and as a result that significant numbers of people would be employed in 'green jobs' that would not exist in a no-carbon policy world. However, any calculation of jobs created in these activities is incomplete if not supplemented with a calculation of the reduced employment in other industries and the decline in the average salary that would result from the associated higher energy costs and lower overall productivity in the economy. This study finds that even after accounting for green jobs, there is a substantial and long-term net reduction in total labor earnings and employment. This is the unintended but predictable consequence of investing to create a 'green energy future.'"

This point about the "green energy future" is not idle speculation, as we are seeing the effects of these policies playing out right now in Europe (see chart below). Consider Germany. Based on a recent story in Reuters ("Special Report: How fracking helps America beat German industry," June 2, 2014), industrial energy consumers in Germany are paying nearly twice as much in electricity costs as their counterparts in the U.S. An international petrochemical manufacturer told Reuters that, due in large part to relative differences in energy prices, it costs $125 million more annually to run a large, modern plant in Germany than in the U.S.

Why the difference? For one, the EU has imposed a price on carbon, which has raised energy costs while having little impact on emissions. Second, Germany itself has made the wrong policy choices: it has shuttered nuclear power plants and imposed expensive mandates to encourage renewable energy over lower cost options like coal and natural gas. We see the same phenomenon in the UK. As *E&E News* reported earlier this year: "The [U.K.] government

places much of the blame for increased energy prices at the feet of so-called green policies. Currently, such policies account for only about 10 percent of the heating bill, but these numbers are set to go up dramatically. According to Department of Energy and Climate Change figures, they will add 33 percent to the cost of electricity by 2020 and 41 percent by 2030. Shutting down old coal-fired power plants and adding more expensive renewable energy -- particularly wind power -- to the grid will spur rising electricity costs."



Given such a significant hit on the economy, we must acknowledge that the U.S. economy is overwhelmingly about small and mid-size business. For example, when counting both employer and non-employer firms, 99.9 percent of U.S. businesses have less than 500 workers, and 98 percent less than 20 employees (according to the latest U.S. Census Bureau data). For good measure, firms with less than 500 employees account for nearly two-thirds of net new jobs and generate approximately 46 percent of the private nonfarm GDP.

• Second, U.S. competitiveness will suffer. Part of the reason for imposing costly EPA regulations on the economy apparently is to somehow spur various developing nations, whose CO2 emissions are growing rapidly, to follow the U.S. But that, of course, would be economic suicide for those nations. The notion that China, India, or other nations that are still struggling to raise themselves out of relative poverty would inflict such massive costs on themselves is naïve, and a dangerous miscalculation for U.S. businesses and workers.

This loss of competitiveness due to higher energy costs spells trouble for U.S. firms in the international marketplace. And while many think of international markets being all about big business, the International Trade Administration (ITA) reports that 98 percent of U.S. goods exporters are smaller firms with less than 500 workers.

• Third, U.S. manufacturers will face increased costs and reduced competitiveness. While all businesses will suffer, let's take a moment to focus on manufacturers. Regarding the EPA regulations, National Association of Manufacturers (NAM) President and CEO Jay Timmons observed: "As users of one-third of the energy produced in the United States, manufacturers rely on secure and affordable energy to compete in a tough global economy, and recent gains are largely due to the abundance of energy we now enjoy. Today's proposal from the EPA could

singlehandedly eliminate this competitive advantage by removing reliable and abundant sources of energy from our nation's energy mix. It is a clear indication that the Obama Administration is fundamentally against an 'all-of-the-above' energy strategy, and unfortunately, manufacturers are likely to pay the price for this shortsighted policy."

And as reported by TheHill.com ("Business groups close ranks for climate battle," June 2, 2014), "Timmons told reporters that the regulations, if enacted as planned, would simply force manufacturers to move overseas to China or other nations with less stringent standards." Again, Hal Quinn of the National Mining Association echoed these points: "These rules are another step by the administration to take us to a more expensive and less secure energy future. They embody unrealistic measures that move America's electric grid away from the low cost and reliable power our economy needs to grow. These regulations, if finalized, would be a loss for American consumers, manufacturers and businesses nationwide, but especially for those in states that rely on low cost electricity from coal."

• Fourth, keep in mind that manufacturing is mostly about small business. Among employer manufacturing firms, according to the latest Census Bureau data, 98.6 percent have less than 500 workers, and 75.8 percent less than 20 employees. Also, the ITA notes that nearly 97 percent of manufacturing exporters were small and mid-size businesses with less than 500 workers.

• Fifth, in fact, key carbon-based energy sectors are all overwhelmingly populated by small firms as well.

- Among oil and gas extraction employer firms, 91.1 percent have less than 20 employees and 98.5% less than 500 workers.

- Among drilling oil and gas wells employer firms, 79.8 percent have less than 20 employees and 97.6% less than 500 workers.

- Among support activities for oil and gas operations employer firms, 83.3 percent have less than 20 employees and 98.7% less than 500 workers.

- Among oil and gas pipeline and related structures construction employer firms, 65.5 percent have less than 20 employees and 95.3% less than 500 workers.

- Among oil and gas pipeline and related structures construction employer firms, 65.5 percent have less than 20 employees and 95.3% less than 500 workers.

- Among oil and gas field machinery and equipment and manufacturing employer firms, 57.6 percent have less than 20 employees and 91.8% less than 500 workers.

- Among coal mining employer firms, 59.6 percent have less than 20 employees and 93.9% less than 500 workers.

- Among support activities for coal mining employer firms, 68.6 percent have less than 20 employees and 95.5% less than 500 workers.

- Among coal and other mineral and ore merchant wholesaler employer firms, 85.6 percent have less than 20 employees and 93.9% less than 500 workers.

- Among electric power generation, transmission and distribution employer firms, 40.2 percent have less than 20 employees and 92.8% less than 500 workers.

So, the EPA's plan to reduce carbon emissions from power plants in the name of climate change promises to be a horror show for the economy, for household incomes, for jobs, and for small businesses. Indeed, that will be the real and significant threat with whatever regulatory or tax scheme is imposed on carbon-based energy in the name of a climate change agenda.

Thank you for this opportunity to address the Committee, and I will be glad to answer any questions.