S. HRG. 112–975

UPDATE ON THE LATEST CLIMATE CHANGE SCIENCE AND LOCAL ADAPTATION MEASURES

HEARING

BEFORE THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS UNITED STATES SENATE

ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

AUGUST 1, 2012

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

Available via the World Wide Web: http://www.fdsys.gov

U.S. GOVERNMENT PUBLISHING OFFICE

25–111 PDF WASHINGTON : 2017

For sale by the Superintendent of Documents, U.S. Government Publishing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2104 Mail: Stop IDCC, Washington, DC 20402–0001

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

ONE HUNDRED TWELFTH CONGRESS
SECOND SESSION

BARBARA BOXER, California, *Chairman*

MAX BAUCUS, Montana
THOMAS R. CARPER, Delaware
FRANK R. LAUTENBERG, New Jersey
BENJAMIN L. CARDIN, Maryland
BERNARD SANDERS, Vermont
SHELDON WHITEHOUSE, Rhode Island
TOM UDALL, New Mexico
JEFF MERKLEY, Oregon
KIRSTEN GILLIBRAND, New York

JAMES M. INHOFE, Oklahoma
DAVID VITTER, Louisiana
JOHN BARRASSO, Wyoming
JEFF SESSIONS, Alabama
MIKE CRAPO, Idaho
LAMAR ALEXANDER, Tennessee
MIKE JOHANNS, Nebraska
JOHN BOOZMAN, Arkansas

BETTINA POIRIER, *Majority Staff Director*
RUTH VAN MARK, *Minority Staff Director*

C O N T E N T S

UPDATE ON THE LATEST CLIMATE CHANGE SCIENCE AND LOCAL ADAPTATION MEASURES

WEDNESDAY, AUGUST 1, 2012

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

The Committee met, pursuant to notice, at 10 a.m. in room 406, Dirksen Senate Office Building, Hon. Barbara Boxer (Chairman of the Committee) presiding.

Present: Senators Boxer, Inhofe, Lautenberg, Cardin, Whitehouse, Udall, Merkley, Sessions, Crapo, and Boozman.

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

Senator BOXER. Good morning, everybody. I want to welcome my colleagues, and I want to welcome our distinguished panel. Everyone will have an opening statement. We will be 5 minutes, and we will try to stick to it. Go a little bit over, that is fine.

Colleagues, climate change is real. Human activities are the primary cause, and the warming planet poses a significant risk to people and the environment. I believe to declare otherwise is putting the American people in direct danger. The body of evidence is overwhelming. The world's leading scientists agree. And predictions of climate change impacts are coming true before our eyes.

The purpose of this hearing is to share with the Committee the mountain of scientific evidence that has increased substantially over time, time that I believe we should have used to reduce carbon pollution, the main cause of climate change.

In 2011 the National Academy of Sciences released the Final Climate Report. It concluded: "Climate change is occurring. It is caused largely by human activities. It poses significant risks for a broad range of human and natural systems, and the preponderance of evidence points to human activities as the most likely cause for most of the global warming that has occurred over the last 50 years."

Even some former climate deniers now see the light. Just this past weekend, Professor Richard Muller, a self-proclaimed climate skeptic, wrote the following in the New York Times: "Last year, following an intensive research effort involving a dozen scientists, I concluded that global warming was real, and the prior estimates of the rate of warming were correct. I am now going a step further. Humans are almost entirely the cause."

Claims by the remaining skeptics are overcome with an examination of the facts. At the first hearing of this Committee when I became Chairman on January 30, 2007, I invited all Senators to give their views on climate change, all Senators in the U.S. Senate. More than one-third of the Senate spoke out. We put together a book. Do we have that book here? Yes. And this is the way the book looked, and it included the voices of the Senate, colleagues from all different political persuasions.

At that time, Senator McCain wrote we are no longer talking about how climate change will affect our children's lives as we did a few years ago. We are talking about how it already is impacting the world. Drought, declining snow packs, forest fires, melting ice caps, species dislocation, habitat loss, and extreme weather events all are examples of how climate change is impacting us. We need to act to mitigate and adapt to these devastating events. I believe he was right then.

Senator Snowe said Arctic glaciers and polar ice caps millions of years old are melting; sea levels are rising. Our own Federal agency, NOAA, reported that 2006 was the warmest year since regular temperature records began in 1895, and the past 9 years have been the warmest on record. And she was right then.

Now, more than 5 years later, we continue to see evidence that the climate is changing around us through trends in extreme weather. And we simply cannot afford to ignore the warnings. And we have some charts I would like to show.

The first chart shows a wildfire in Bastrop, Texas, that destroyed 1,500 homes in 2011. Chart 2 shows a man in what used to be his home in that area. There is nothing left. Chart 3 is a headline from The Guardian in the United Kingdom, Deadly Heat Waves Will Be More Frequent in Coming Decades Say Scientists. Mega-heat waves like the one estimated to have killed tens of thousands in Western Europe in 2002 will become up to 10 times more likely over the next 4 years, a study suggests.

There are many examples of how the climate is continuing to change around us. NOAA reported in June that the previous 12 months had been the warmest 12-month period the nation has experienced since recordkeeping began in 1895. Many cities set all-time temperature records during the month of June. Over 170 all-time warm temperature records were broken or tied.

As of July 3rd, 56 percent of the U.S. experienced moderate to exceptional drought conditions. Scientists at NOAA have confirmed the record breaking Texas drought was strongly influenced by climate change.

NASA reported last month that an iceberg twice the size of Manhattan—you could see the size of that iceberg—broke off of Greenland, a phenomenon that is expected to be repeated as the climate continues to warm. Scientists have also linked warming of the oceans to the emergence of a group of bacteria in the Baltic Sea in Northern Europe. These recent event make it clear that the climate continues to change, and the likelihood of extreme events is growing greater which puts our nation, and puts our people, at risk.

In 2008 Congress blocked action. We needed six more votes to take action on climate change. But Congress blocked action, and we

have lost valuable time. But progress has been made. The Obama administration deserves credit for moving forward with measures to reduce pollution and improve the nation's energy efficiency. New automobile efficiency will reduce carbon pollution by over 6 billion tons while saving consumers $1.7 trillion in fuel costs.

The GSA has reduced energy consumption by 20 percent over 2003 levels. By 2020 the GSA expects to increase its renewable energy production and procurement to 30 percent of annual energy consumption.

According to the Brookings Institution, in 2010 2.7 million workers were employed at more than 40,000 companies across the nation in the clean energy sector. And bipartisan proposals, such as the Bennet-Isakson SAVE Act which would reduce barriers to home energy efficiency improvements, offer ways to reduce harmful carbon pollution.

So, colleagues, we cannot turn away from the mountain of evidence that climate change has already started to impact the planet and will only grow worse without action. Leading scientists who are testifying today on the latest science will reinforce that point.

Taking action to address this serious problem will benefit us, will benefit us and future generations, will actually reduce energy costs in the long-term for our people, make us energy independent, and create millions of jobs.

So, I look forward to hearing from the witnesses. But before we do that, we will hear from colleagues. And this is one that is a little bit different than a highway bill.

[Laughter.]

Senator BOXER. You may see a few disagreements on this panel.

With that I would call on my friend, Senator Inhofe, for his statement.

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

Senator INHOFE. Thank you, Madam Chairman.

In a way it should not be any different from the highway bill. We just have different beliefs, different ideas, and that is what this is all about today.

Senator BOXER. Yes.

Senator INHOFE. And so, this seems like the good old days. We used to have these hearings all the time. It has been, what, since February 2009, I think, since we had one of these on the science. So I am glad we are back to doing it now.

Back then we heard promises from the Obama administration of the clean energy revolution with green jobs and propped up by billions of taxpayer dollars going to companies like Solyndra. What came of all those promises? The global warming movement has completed collapsed, and the cap and trade is dead and gone.

I suspect a look back over the past 3 years will be a little painful for some. In 2009 the Democratic President, overwhelming majority in the House and the Senate, the majorities, the global warming alarmists were on top of the world. They thought they would reach their goal and have an international agreement. All of that was there. I mean, why not? We had a Democrat President, Democrat majorities in the House and the Senate.

It did not happen. Of course, what drove the collapse of the global warming movement was the science of the United Nations Intergovernmental Panel on Climate Change. It was finally exposed, I had been exposing it for some time, but it actually was exposed when Climategate came.

And here is something interesting. I am going to read this into the record. These are publications that were on the alarmist side of this issue. And yet the change that took place, the New York Times editorial, "Given the stakes, the IPCC cannot allow more missteps, and at the very least, must tighten its procedures and make its deliberations more transparent." The panel's chairman, again, quoting from the editorial, is under fire for taking consulting fees from business interests.

The Washington Post: "Recent revelations about the flaws in that seminal IPCC report ranging from typos in key dates to sloppy resourcing are undermining confidence not only in the panel's work, but also in the projections about climate change." Newsweek, some of the IPCC's most quoted data in recommendations were taken straight out of unchecked activist brochures and newspaper articles. The U.K. Daily Telegraph on Climategate, Climategate is the worst scientific scandal of our generation.

This is the science on which all of these things have been based. Now, how unpopular is the global warming movement now? The Washington Post recently published a poll revealing that Americans no longer worry about global warming, and one of the reasons is that they do not trust the scientists and their motives.

The IPCC has even lost trust in the left. Andrew Revkin of the New York Times—he was one that was always on that side—recently called for the IPCC Chair, Pachauri, to make a choice between global warming activism and leading the IPCC. They are also saying similar things about global warming alarmist James Hansen. As David Roberts of Grist acknowledged, Hansen has become, quoting now, so politicized that people tend to dismiss him.

Just one look at this Committee and we can see how bad things have gotten for the alarmists. Today, there are no Federal witnesses here to testify, as was called out in an article this morning, I think it was in Politico. President Obama himself never dares mention global warming. He will not say the term. And some of the left have noticed that Bill McKibben recently criticized the President for not attending the Rio + 20 and acknowledged that 20 years ago George Bush did attend. And Obama did not even attend.

It has got to be very hard for my friends on the left to watch the President who promised he would slow the rise of oceans posing in front of pipelines in my home State of Oklahoma pretending to like oil and gas. I imagine they are trying to keep quiet because they know that President Obama is still moving forward with his global warming agenda. They just do not want the American people to know it.

Now, what the American people do not know, President Obama is doing, through his bureaucracy, what he could not do legislatively. And we have already identified $68.4 billion that has been spent on his global warming agenda. And people are not even aware of it. He did it without any authorization from Congress.

Today, we should have a fascinating debate. I want to thank Climatologist Dr. John Christy for appearing before the Committee to provide his insights. I am also looking forward to testimony from Margo Thorning, as we have heard from her before, and it will be very good.

Let me just—we have been through this now for the past 3 and a half years, and the results are clear. President Obama's green energy agenda has been a disaster. The time has come to put these tired, failed policies to rest and embrace the United States' energy boom so that we can put Americans back to work, turn this economy around, become totally energy independent from the Middle East, and ensure energy security for the years to come.

I really believe this. We, just in the last couple of years—no one is going to deny the fact that we have more recoverable reserves in coal, oil, and gas than any other country. We could be totally independent. And those who say we have got to have green energy to become independent from the Middle East, we can do that now, just doing what every other country in the world does, and that is develop our own resources.

And while I made the comment about the President not saying the words global warming, let me compliment one of my fellow Senators. Senator Sanders had read my book and was down on the floor on Monday and I happened, when I got off the plane and came in, there are people like Senator Sanders, in his heart, he believes everything that he says. There is no hypocrisy in him. And you see a lot of that in Washington.

But you do not see as much of the people who sincerely are willing to fight for the things that they believe in, as is Senator Sanders. I said this on the Senate floor. And I say it again. And I know he believes everything that he says. He knows that I believe, in my heart, everything that I say.

So, I was talking to Senator Cardin on the elevator coming up here, and we both said, is that not what the Senate is supposed to do? All of us represent different people, different philosophies, say what we really believe. And I think that is a healthy thing.

Thank you, Madam Chairman.

[The prepared statement of Senator Inhofe follows:]

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

I must say it feels like we're back to the good old days. It may be hard to believe, but it was in February 2009, during the height of the global warming alarmist movement, that this Committee last held a hearing on global warming science. Back then we heard promises from the Obama administration of a clean energy revolution with green jobs propped up by billions in taxpayer dollars to companies like Solyndra.

What came of all those promises? The global warming movement has completely collapsed, and cap and trade is dead and gone.

I suspect a look back over the past 3 years will be a little painful for my friends on the other side. In 2009, with a Democratic President and overwhelming Democratic majorities in the House and the Senate, global warming alarmists were on top of the world—they thought they would finally reach their goal of an international agreement that would eliminate fossil fuels. Yet the Waxman-Markey cap and trade bill didn't happen.

Of course, what drove the collapse of the global warming movement was that the science of the United Nations Intergovernmental Panel on Climate Change (IPCC) was finally exposed. For years I had warned that the United Nations was a political body, not a scientific body—and finally the mainstream media took notice:

New York Times editorial: "Given the stakes, the IPCC cannot allow more missteps and, at the very least, must tighten procedures and make its deliberations more transparent. The panel's chairman . . . is under fire for taking consulting fees from business interests . . . " (February 17, 2010)

The Washington Post: "Recent revelations about flaws in that seminal IPCC report, ranging from typos in key dates to sloppy sourcing, are undermining confidence not only in the panel's work but also in projections about climate change."

Newsweek: "Some of the IPCC's most-quoted data and recommendations were taken straight out of unchecked activist brochures, newspaper articles . . . "

UK Daily Telegraph on Climategate: "The worst scientific scandal of our generation."

Just how unpopular is the global warming movement now? The Washington Post recently published a poll revealing that Americans no longer worry about global warming, and one of the reasons is because they don't trust the scientists' motivations.

The IPCC has even lost the trust of the left. Andrew Revkin of the New York Times recently called for IPCC chair Pachauri to make a choice between global warming activism and leading the IPCC. They are also saying similar things about global warming alarmist James Hansen. As David Roberts of Grist acknowledged, Hansen has "become so politicized that people tend to dismiss him."

Just one look at this Committee and we can see how bad things have gotten for the alarmists: today there are no Federal witnesses here to testify about the grave dangers of global warming. President Obama himself never dares to mention global warming, and some on the left have noticed: Bill McKibben recently criticized the President for not attending the Rio + 20 sustainability conference, noting that, "Unlike George H.W. Bush, who flew in for the first conclave, Barack Obama didn't even attend."

It must be very hard for my friends on the left to watch the President who promised he would slow the rise of the oceans posing in front of pipelines in my home State of Oklahoma pretending to support oil and gas.

I imagine they are trying to keep quiet because they know President Obama is still moving forward with his global warming agenda—he just doesn't want the American people to know about it.

Now what the American people don't know: President Obama is doing through his bureaucracy what he couldn't do legislatively. He is spending billions of taxpayer dollars on his global warming agenda. We've already identified $68 billion.

Today we should have a fascinating debate. I want to thank climatologist Dr. John Christy for appearing before the Committee to provide his insights. I am also looking forward to the testimony of Dr. Margo Thorning, a noted economist who will discuss the economic pain of the Obama EPA's current regulations.

We've been through this now for the past 3 and a half years, and the results are clear: President Obama's green energy agenda has been a disaster. The time has come to put these tired, failed policies to rest and embrace the U.S. energy boom so that we can put Americans back to work, turn this economy around, become totally energy independent from the Middle East, and ensure energy security for years to come.

Senator BOXER. Thank you very much, Senator.

I want to clear two things up. I did not ask for any witnesses from the Administration. I wanted outside scientific voices because I did not want to see this turn into an attack on the Obama administration. Clearly, clearly, it is still is turning into that, but that is OK. I did not want to have a witness become the face of the Obama administration because they have done a lot on this.

And I want to put in the record what I talked to before. Because you heard my colleague say, no jobs, nothing further. Let me just say something here. We are going to put in the record the report from the Brookings Institution. They said the clean economy which employs some 2.7 million encompasses a significant number of jobs in establishments spread across a diverse group of industries. Though modest in size, the clean economy employs more workers than the fossil fuel industry.

So, let us just get this straight. Yes, the Obama administration has taken some steps. And yes, we have seen job creation. We will put that in the record.

And we will call on Senator Sanders.

[The referenced information follows:]

SIZING THE CLEAN ECONOMY

A NATIONAL AND REGIONAL GREEN JOBS ASSESSMENT

Metropolitan Policy Program
at BROOKINGS

CONTENTS

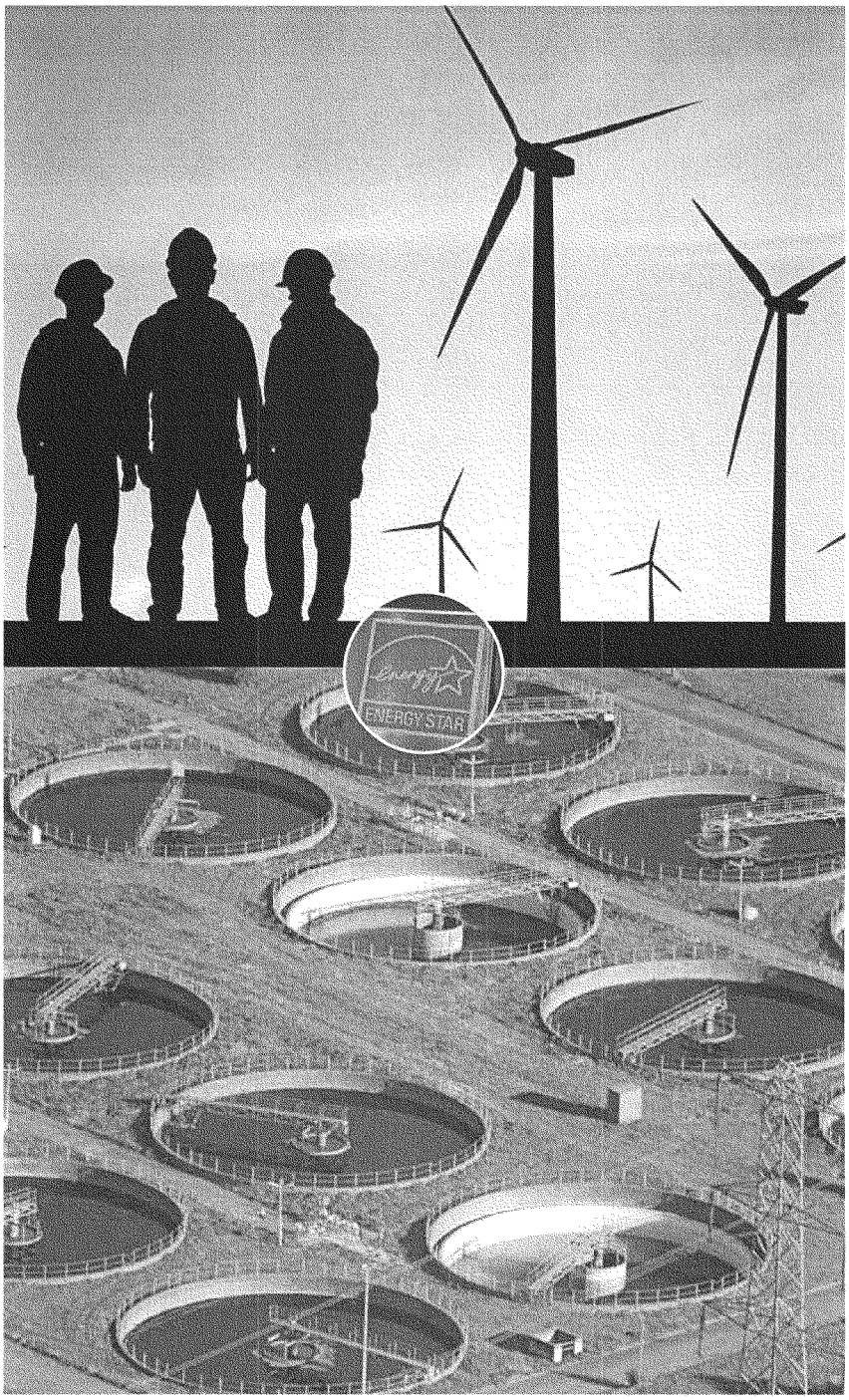
10

SIZING THE CLEAN ECONOMY

A NATIONAL AND REGIONAL GREEN JOBS ASSESSMENT

BY MARK MURO, JONATHAN ROTHWELL, AND DEVASHREE SAHA
WITH BATTELLE TECHNOLOGY PARTNERSHIP PRACTICE

THE BROOKINGS INSTITUTION | METROPOLITAN POLICY PROGRAM | 2011


ENERGY STAR

12

EXECUTIVE SUMMARY

The "green" or "clean" or low-carbon economy—defined as the sector of the economy that produces goods and services with an environmental benefit—remains at once a compelling aspiration and an enigma.

As a matter of aspiration, no swath of the economy has been more widely celebrated as a source of economic renewal and potential job creation.

Again this year President Obama spoke in his State of the Union Address of "the promise of renewable energy" and environmental pursuits that will "strengthen our security, protect our planet, and create countless new jobs for our people." Since then, a global "race to clean" has gained new urgency with numerous nations—such as China, Japan, and the United Kingdom—all having made new commitments to invest in the low-carbon and environmental goods sector as a source of quality jobs, exports, and industry growth.

Yet, the clean economy remains an enigma: hard to assess. Not only do "green" or "clean" activities and jobs related to environmental aims pervade all sectors of the U.S. economy; they also remain tricky to define and isolate—and count.

The clean economy has remained elusive in part because, in the absence of standard definitions and data, strikingly little is known about its nature, size, and growth at the critical regional level.

Currently no comprehensive national database exists on the spatial geography of the clean economy and its sub-industries, although important work has assessed the clean economy across states. And while numerous studies have analyzed individual regional clean or green industries, a proliferation of definitions and the absence of data for large numbers of regions has made it difficult to situate regional clean economies in a national and comparative context.

The result: Debates about the so-called "green" economy and "green jobs" have frequently been short on facts and long on speculation, assertion, and partisanship.

Which gets to the impetus of this report: Seeking to address some of these problems, the Metropolitan Policy Program at Brookings worked with Battelle's Technology Partnership Practice to develop, analyze, and comment on a detailed database of establishment-level employment statistics pertaining to a sensibly defined assemblage of clean economy industries in the United States and its metropolitan areas.

Covering the years 2003 to 2010 for every county in the United States, the resulting information (available for download at http://www.brookings.edu/metro/clean_economy.aspx) and this report represent the first study of the U.S. clean economy to provide timely information that is both comprehensive enough in its scope and detailed enough in its categorization to inform national, state, and regional leaders on the dynamics of the U.S. low-carbon and environmental goods and services "super-sector" as they are transpiring in regions and metropolitan areas. This information is then employed in a discussion of how the nation, the states, and localities and regions might address a number of key policy problems that may be slowing the growth of the clean economy.

Most importantly, "Sizing the Clean Economy: A National and Regional Green Jobs Assessment" concludes that:

- **The clean economy, which employs some 2.7 million workers, encompasses a significant number of jobs in establishments spread across a diverse group of industries.** Though modest in size, the clean economy employs more workers than the fossil fuel industry and bulks larger than bioscience but remains smaller than the IT-producing sectors. Most clean economy jobs reside in mature segments that cover a wide swath of activities including manufacturing and the provision of public services such as wastewater and mass transit. A smaller portion of the clean economy encompasses newer segments that respond to energy-related challenges. These include the solar photovoltaic (PV), wind, fuel cell, smart grid, biofuel, and battery industries

- **The clean economy grew more slowly in aggregate than the national economy between 2003 and 2010, but newer "cleantech" segments produced explosive job gains and the clean economy outperformed the nation during the recession.** Overall, today's clean economy establishments added half a million jobs between 2003 and 2010, expanding at an annual rate of 3.4 percent. This performance lagged the growth in the national economy, which grew by 4.2 percent annually over the period (if job losses from establishment closings are omitted to make the data comparable). However, this measured growth heavily reflected the fact that many longer-standing companies in the clean economy—especially those involved in housing- and building-related segments—laid off large numbers of workers during the real estate crash of 2007 and 2008, while sectors unrelated to the clean economy (mainly health care) created many more new jobs nationally. At the same time, newer clean economy establishments—especially those in young energy-related segments such as wind energy, solar PV, and smart grid—added jobs at a torrid pace, albeit from small bases

- **The clean economy is manufacturing and export intensive.** Roughly 26 percent of all clean economy jobs lie in manufacturing establishments, compared to just 9 percent in the broader economy. On a per job basis, establishments in the clean economy export roughly twice the value of a typical U.S. job ($20,000 versus $10,000). The electric vehicles (EV), green chemical products, and lighting segments are all especially manufacturing intensive while the biofuels, green chemicals, and EV industries are highly export intensive

- **The clean economy offers more opportunities and better pay for low- and middle-skilled workers than the national economy as a whole.** Median wages in the clean economy—meaning those in the middle of the distribution—are 13 percent higher than median U.S. wages. Yet a disproportionate percentage of jobs in the clean economy are staffed by workers with relatively little formal education in moderately well-paying "green collar" occupations

- **Among regions, the South has the largest number of clean economy jobs though the West has the largest share relative to its population.** Seven of the 21 states with at least 50,000 clean economy jobs are in the South. Among states, California has the highest number of clean jobs but Alaska and Oregon have the most per worker

- **Most of the country's clean economy jobs and recent growth concentrate within the largest metropolitan areas.** Some 64 percent of all current clean economy jobs and 75 percent of its newer jobs created from 2003 to 2010 congregate in the nation's 100 largest metro areas

- **The clean economy permeates all of the nation's metropolitan areas, but it manifests itself in varied configurations.** Metropolitan area clean economies can be categorized into four-types: service-oriented, manufacturing, public sector, and balanced. New York, through mass transit, embodies a service orientation; so does San Francisco through professional services and Las Vegas through architectural services. Many Midwestern and Southern metros like Louisville; Cleveland; Greenville, SC; and Little Rock—but also San Jose in the West—host clean economies that are heavily manufacturing oriented. State capitals are among those with a disproportionate share of clean jobs in the public sector (e.g. Harrisburg, Sacramento, Raleigh, and Springfield). Finally, some metros—such as Atlanta; Salt Lake City; Portland, OR; and Los Angeles—balance multi-dimensional clean economies

- **Strong industry clusters boost metros' growth performance in the clean economy.** Clustering entails proximity to businesses in similar or related industries. Establishments located in counties containing a significant number of jobs from other establishments in the same segment grew much faster than more isolated establishments from 2003 to 2010. Overall, clustered establishments grew at a rate that was 1.4 percentage points faster each year than non-clustered (more isolated) establishments. Examples include professional environmental services in Houston, solar photovoltaic in Los Angeles, fuel cells in Boston, and wind in Chicago

The clean economy permeates all of the nation's metropolitan areas, but it manifests itself in varied configurations.

The measurements and trends presented here offer a mixed picture of a diverse array of environmentally-oriented industry segments growing modestly even as a sub-set of clean energy, energy efficiency, and related segments grow much faster than the nation (albeit from a small base) and in

ways that are producing a desirable array of jobs, including in manufacturing and export-oriented fields.

As to what governments, policymakers, and regional leaders should do to catalyze faster and broader growth across the U.S. clean economy, it is clear that the private sector will play the lead role, but governments have a role too. In this connection, the fact that significant policy uncertainties and gaps are weakening market demand for clean economy goods and services, chilling finance, and raising questions about the clean innovation pipeline reinforces the need for engagement and reform. Not only are other nations bidding to secure global production and the jobs that come with it but the United States currently risks failing to exploit growing world demand. And so this report concludes that vigorous private sector-led growth needs to be co-promoted through complementary engagements by all levels of the nation's federal system to ensure the existence of well-structured markets, a favorable investment climate, and a rich stock of cutting-edge technology–as well as strong regional cast to all efforts.

Along these lines, the report recommends that governments help:

- **Scale up the market by taking steps to catalyze vibrant domestic demand for low-carbon and environmentally-oriented goods and services.** Intensified "green" procurement efforts by all levels of government are one such market-making engagement. But there are others. Congress and the federal government could help by putting a price on carbon, passing a national clean energy standard (CES), and moving to ensure more rational cost recovery on new transmission links for the delivery of renewable energy to urban load centers. States can adopt or strengthen their own clean energy standards, reduce the initial costs of energy efficiency and renewable energy adoption, and pursue electricity market reform to facilitate the use of clean and efficient solutions. And localities can also support adoption by expediting permitting for green projects, adopting green building and other standards, and adopting innovative financing tools to reduce the upfront costs of investing in clean technologies

- **Ensure adequate finance by moving to address the serious shortage of affordable, risk-tolerant, and larger-scale capital that now impedes the scale-up of numerous clean economy industry segments.** On this front Congress should create an emerging technology deployment finance entity to address the commercialization "Valley of Death" and also work to rationalize and reform the myriad tax provisions and incentives that currently encourage capital investments in clean economy projects. States, for their part, can supplement private lending activity by providing guarantees and participating loans or initial capital for revolving loan funds targeting clean economy projects using new or improved technologies. And for that matter regions and localities can also help narrow the deployment finance gap by helping to reduce the costs and uncertainty of projects by expediting their physical build-out, whether by managing zoning and permitting issues or even pre-approving sites

- **Drive innovation by investing both more and differently in the clean economy innovation system.** With the needed major scale-up of investment levels unlikely for now, Congress at least needs to embrace continued incremental growth of key energy and environmental research, development, and demonstration (RD&D) budgets. At the same time, Congress should continue its recent institutional experimentation through measured expansion of such recent start-ups as the Energy Frontier Research Centers, ARPA-E, and Energy Innovation Hubs programs. Two worthy additional experiments would be the creation of a water sciences innovation center and the establishment of a regional clean economy consortia initiative. States can also advance the clean economy through maintaining and expanding their own RD&D efforts, perhaps by tapping state clean energy funds where they exist. All should be focused and prioritized through a rigorous, data-driven analysis of the nature, growth, and strengths of local clean economy innovation clusters

In addition, the "Sizing the Clean Economy" emphasizes that in working on each of these fronts federal, state, and regional leaders need to:

- **Focus on regions, meaning that all parties need to place detailed knowledge of local industry dynamics and regional growth strategies near the center of efforts to advance the clean economy.** While the federal government should increase its investment in new regional innovation and industry cluster programs such as the Economic Development Administration's i6 Green Challenge, states should work to improve the information base about local clean economy industry clusters and move to support regionally crafted initiatives for advancing them. Regional actors, meanwhile, should take the lead in using data and analysis to understand the local clean economy in detail; identify competitive strengths; and then move to formulate strong, "bottom up" strategies for overcoming key clusters' binding constraints. Employing cluster intelligence and strategy to design and tune regional workforce development strategies will be a critical regional priority

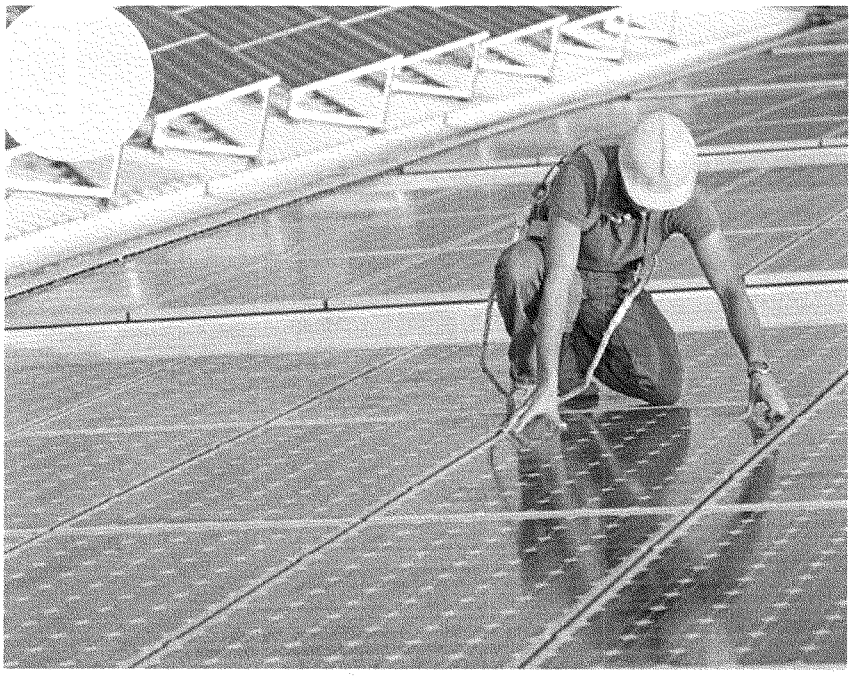
* * *

The measurements, trends, and discussions offered here provide an encouraging but also challenging assessment of the ongoing development of the clean economy in the United States and its regions. In many respects, the analysis warrants excitement. As the nation continues to search for new sources of high-quality growth, the present findings depict a sizable and diverse array of industry segments that is–in key private-sector areas–expanding rapidly at a time of sluggish national growth. With smart policy support, broader, more rapid growth seems possible. At the same time, however, the information presented here is challenging, most notably because the growth of the clean economy has almost certainly been depressed by significant policy problems and uncertainties.

In that sense, what is most challenging here is the fundamental question raised by the dynamic growth but modest size of the most vibrant and promising segments of the clean economy.

That question is: Will the nation marshal the will to make the most of those industries?

In the end, it is a question raised frequently by these pages.



INTRODUCTION

The "green" or "clean" or low-carbon economy—defined as the sector of the economy that produces goods and services with an environmental benefit—remains at once a compelling aspiration and an enigma as the nation and its regions search for new sources of growth.

As a matter of aspiration, no swath of the economy has been more widely celebrated as a source of economic renewal and potential job creation.

Again this year President Obama spoke in his State of the Union Address of "the promise of renewable energy" and environmental pursuits that will strengthen our security, protect our planet, and create countless new jobs for our people."

Likewise, scores of nations, dozens of states, and hundreds of U.S. regions and localities continue to beat the drum for the economic, security, and environmental benefits of clean and green industry development.

Most notably, a global "race to clean" has now emerged, with numerous nations working to drive low-carbon and environmental industry growth.

China—which now produces half of the world's wind turbine and solar modules—recently announced it would accelerate its "clean revolution" over the next five years and has set out aggressive growth plans for strategic emerging industries (SEIs) critical to economic restructuring, including multiple new energy categories, electric vehicles, and energy efficiency products.[1]

Japan, in response to the Fukishima nuclear accident, has committed to achieving massive price reductions for solar

generation as part of a new renewables-oriented energy policy that will drive economic change through massive investments and yet-to-be-determined innovation.[2]

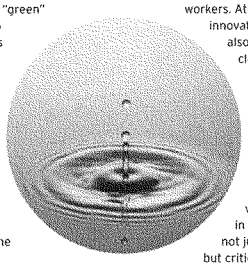
And, for its part, Britain's Conservative-led coalition government recently outlined plans for the world's first state-backed green investment bank aimed at laying the foundation for clean industry growth.[3]

In short, while the emergence of the green or low-carbon economy originally flowed from environmental concerns, a market vision now prevails—a vision in which new jobs and industries flow from the drive to reduce the environmental impacts of the economy.

Along these lines, momentum for the business of "green" flows in part from the $154 billion in private capital invested worldwide in 2010 in renewable energy alone (up 650 percent from 2004) and, looking forward, from the projected tripling to $2.2 trillion by 2020 of the broader world low-carbon energy market.[4] Or as Dow Chemical Company CEO Andrew Liveris wrote recently: "A renaissance is within reach. If Americans are the ones who design and build the new [clean economy] technologies it will re-energize commerce in the United States, creating, without a doubt, millions of high-paying jobs."[5]

Such is the current form of the "green" economy aspiration.

And yet, for all that the clean economy also remains an enigma: hard to assess. Not only do "green" or "clean" activities and jobs related to environmental aims pervade all sectors of the U.S. economy; they also remain tricky to define and isolate—and count.



The clean economy, in this regard, is not only, or even mostly, a matter of dramatic and highly visible wind farms and solar parks. It also includes barely visible "green" variants of existing industries like food and appliance manufacturing along with industries such as sewage treatment or recycling whose environmental activities are so mundane as to be barely noticeable.

But above all, the clean economy has also remained elusive because—in the absence of standard definitions and data—strikingly little is known about its nature, size, and growth at the critical regional level where it comes to ground.

Currently no comprehensive national database exists on the spatial geography of the clean economy and its sub-industries, although important work has assessed the clean economy across states.[6] And while numerous studies have analyzed individual regional clean or green industries, a proliferation of definitions and the absence of data for large numbers of regions has made it difficult to situate regional clean economies in a national and comparative context. The upshot has been that national, state, and regional economic development actors of all kinds are largely without the high-quality, consistent, fine-grained data they need to set strategy and develop initiatives to advance the clean economy.

The result: Debates about the so-called "green" economy and "green jobs" have frequently been short on facts and long on speculation, assertion, and partisanship.

Hence this report: Seeking to address some of these problems, the Metropolitan Policy Program at Brookings worked with Battelle's Technology Partnership Practice to develop a detailed database of establishment-level employment in a sensibly defined assemblage of clean economy industries covering every county in the United States over the years 2003 to 2010. In that fashion, the pages that follow represent the first study of the U.S. clean economy to provide timely information that is both comprehensive enough in its scope and detailed enough in its categorization to inform national, state, and regional leaders on the recent employment dynamics of the U.S. low-carbon and environmental goods and services super-sector as they are transpiring in individual U.S. regions and metropolitan areas. Moreover, to begin promoting a greater continuity with other information, the definitions and measurements here anticipate the approach and structure of the federal government's own forthcoming "green economy" count, due sometime next year at broader levels of geography.

What does the inquiry find? Overall, the analysis depicts a clean economy that encompasses a modest-sized but growing and layered mix of diverse industries that varies widely in its distribution across U.S. metropolitan areas. To the growth question, while the clean economy's aggregate employment growth remained modest in the 2000s (current clean economy employers added nearly half a million jobs between 2003 and 2010), young, high-profile renewable energy, energy efficiency, and related industries delivered hyper-growth, albeit from relatively small bases.

Turning to the nature of the super-sector's jobs, the new data confirm that the clean economy is in fact delivering on hopes that it would generate a diverse array of quality positions that are at once more export- and more production-oriented than is the rest of the economy. Clean economy jobs tilt toward manufacturing and exporting and provide more opportunities with better pay for lower-skilled workers. At the same time, a cadre of highly trained innovators—scientists, engineers, architects—are also disproportionately demanded by the clean economy.

Beyond that, one of the most important findings of this report has to do with the growth-promoting role of regional industry concentrations. Job growth in the clean economy has been significantly faster in regional industry clusters than elsewhere. This means that understanding the region-by-region variation of the clean economy—whether in Albany or Little Rock or San Francisco—is not just an "interesting" bit of local color but critical for understanding the competitive strengths and potential of the clean economy wherever it is found. Gaining a sharper understanding of the nature and working of these concentrations can help national, state, and regional decision-makers identify centers of strength and focus strategies and investments for maximum growth in a time of limited resources.

So this report aims also to help clarify some of what has remained opaque about the nation's and its regions' clean economy.

To that end, the report begins by noting why the metropolitan clean economy matters and then proceeds to describe the definition, methods, and data used here to measure the clean economy nationally and across various levels of geography, with a focus on the 100 largest U.S. metro areas. After that, the report reviews a series of measurements and trends that characterize the development of the clean economy across the nation and its regions. Finally, the report discusses those trends, and concludes by commenting on a number of policy problems that may be slowing the growth of the clean economy and suggesting some priorities for federal, state, regional, and private-sector work to advance clean economy growth.

In the end, the main takeaway is simple: The clean economy, as it stands today, is not a myth. It is real, ubiquitous, and growing—in some segments rapidly. And yet, for all that, too little is clearly known about the sector, which remains nascent, and which has not profited from the sort of policy environment that would best catalyze its growth. For all of those reasons, it is time to assemble the facts and decide as a nation of regions how best to make the most of the emergence of the clean economy.


fuel
fail

II

WHY THE METROPOLITAN CLEAN ECONOMY MATTERS

There is no doubt that the "clean," or "green," economy looms large in global, national, and regional economic debates.

But why? Why should this particular swath of establishments, firms, and industries matter inordinately to national and metropolitan leaders?

Further, what is so important about the metropolitan clean economy?

There are multiple answers to these questions—including the possibility that the future growth of the clean economy will be sizable—but the most important ones involve the interconnection of these industries with some of the most fundamental issues of present day economic life.

The clean economy matters because its emergence responds to critical global and national environmental, security, and economic trends.

To begin with, the clean economy merits attention because its growth responds to worldwide megatrends associated with critical national and world challenges—notably the growing demand for global environmental sustainability, the sharpening need for resource security, and the aspiration everywhere toward economic transformation.[1]

Global demand for environmental sustainability. The clean economy matters, first of all, because its emergence reflects a growing demand for environmental sustainability given growing concerns about the already massive scale of global and national environmental deterioration.[2]

At the global scale, steady population growth is exerting increasing pressure on scarce resources. A dozen years after reaching 6 billion people, the earth's population will grow to 7 billion later this year, probably 9 billion before 2050, and over 10 billion by 2100.[3] Over the same period, economic development and the growing wealth of rising nations will propel over 1 billion more people into the global middle class. These new, mostly urbanized consumers will purchase energy-intensive goods like appliances and automobiles for the first time, upgrade towards land- and water-intensive diets comprised of more meat and fewer basic staples, and generate increasing amounts of waste—all placing new pressures on world resources.[4]

An already stressed planet will be further strained in coming decades. On the water front, the U.N. reckons that after growing at a steady rate of 2 percent per year for the past half century, global demand for water has posted a long-term step change increase and will grow at 3 percent per year into the future.[5] Consulting firm McKinsey & Co. sees a 40 percent shortfall between existing water supplies and projected demand in 2030 absent efficiency gains.[6] Global energy consumption, for its part, is projected to increase perhaps 50 percent in the years to 2035.[7] Yet if catastrophic climate change is to be averted, greenhouse gas (GHG) emissions from the combustion of conventional fossil fuels must be *reduced* substantially.[8]

Which points to another environment-related driver of clean economy growth: the likelihood of more and more stringent regulatory responses to the sustainability challenge around the world. Notwithstanding the collapse in late 2009 of efforts to craft a single global agreement to reduce GHG emissions and the foundering of congressional efforts to institute a "cap and trade" carbon pricing

system, unprecedented national emission reduction targets were agreed to by over 75 countries at varying stages of development (including the United States) as part of the scaled-back Copenhagen Accord.[9] Nations and major states in the United States have enacted no fewer than 293 binding and accountable new emissions reduction commitments since June 2008.[10] Looking forward, continued environmental concern in the United States and around the world will almost certainly motivate the adoption of additional environmental standards that will sharpen demand for low-carbon or environment-friendly goods and services.

The bottom line: Environmental stress and policy responses to it are driving and will continue to drive waves of industrial change. Just as the growth of a post-war environmental consciousness (reflected in the Clean Air and Water Acts in the U.S.) drove the emergence of a first generation of clean economy industries such as recycling, pollution control, and remediation, concern about global sustainability and climate change are spurring the growth of a new set of energy related industries today—with more change inevitable.[11]

The largest 100 metros contain 63 percent of the nation's residential structures, 64 percent of the nation's vehicle miles traveled, and account for 56 percent of the nation's carbon emissions.

A sharpening need for resource security. The clean economy also matters for reasons of resource security: it reflects new demands that this nation and others reduce their vulnerability to resource supply shocks and related conflict.[12]

Currently, the United States consumes nearly 19 million barrels of oil per day—half of it imported—to power its economy, move its people and products, and manufacture its goods.[13] That leaves the entire U.S. economy vulnerable to geopolitical instability and supply disruptions abroad.[14] For example, the high and volatile energy prices of 2008 warned of a new, tighter, and more uncertain reality on the world market for fossil fuels, particularly oil.[15] Today, economic recovery, the return of oil prices to over $100 per barrel, and the Arab Awakening's uncertain course in the Middle East and North Africa have only sharpened these concerns. And rightly so: Such uncertainty and price volatility has been shown to reduce investment across the economy, increase business costs, disrupt household budgets, and so depress domestic growth.[16]

However, the "green" and low-carbon goods, processes, and services being developed by the clean economy represent an opportunity for the nation to insulate itself from price and supply shocks and begin to disentangle itself from the messy geopolitics of oil through efficiency advances and a diversification of the nation's energy-source portfolio.[17]

In this connection, environmentally-oriented technologies and processes will likely contribute to resource security by reducing the environmental impact of exploiting the fossil fuels that are already abundant in energy-hungry countries like the U.S. and China, such as coal and shale gas—making uptake manageable by mitigating their adverse effects. Coal will remain an important source for generating electricity well into the future so it is likely that end-of-pipe mitigation technologies and carbon capture and sequestration systems will emerge as critical aspects of its use. Likewise, water and drainage treatment technologies are already seeing significant new demand associated with managing the substantial flows of contaminated "process" water generated by the hydraulic fracturing techniques used in extracting gas and oil from shale deposits.[18]

Paralleling these dynamics are stresses involving the world's water resources. Water security threatens to become a flashpoint in many already volatile regions of the world where supplies are at once scarce (the Middle East), facing significant pressure in demand (South and East Asia), and vulnerable to a changing climate (everywhere).[19] Since agriculture soaks up 70 percent of the water consumed globally, changes in water supply—which will be how climate change most tangibly affects daily human activity—will have direct and global effects on food security.[20] Exacerbating the issue, much of the population growth mentioned above will take place in regions with already overburdened or underdeveloped water infrastructure.[21] Yet here, too, the water-related industries of the clean economy hold out the hope of minimizing shortfalls (and so conflict) and securing supplies through efficiency gains and advancements in purification, management, and recycling technologies.[22]

A world-wide aspiration toward economic transformation. Finally, there remains a third increasingly ascendant factor behind the clean economy's significance: the prospect of industrial transformation. The clean economy matters, in short, because it interacts with nearly every aspect of the rest of the economy and is emerging as a site of rapid technological and process innovation world-wide.

Innovation, after all, remains a crucial driver of economic growth, and so clean economy innovation—motivated by the unprecedented environmental and resource challenge outlined above—appears a likely source of future economic development as firms of all kinds seek to invent new, environmentally friendly ways to decrease the world's carbon and resource intensity.[23]

In fact, the likelihood of transformation is already attracting investment. Some $1 trillion in investment capital globally flowed into clean energy segments alone between 2004 and 2010, as yearly investment levels nearly quintupled from $52 billion to $243 billion.[24] Looking forward, a recent survey by Ernst & Young found that three-quarters of major global corporations plan to increase their "cleantech" budgets from 2012 to 2014 and that 40 percent of that spending will flow into R&D.[25] Turning to water, the prospect of innovation is also attracting increased investor attention. Most notably, venture capital (VC) firms poured nearly $1.25 billion into the historically staid sector between 2005 and 2010 through close to 250 separate deals.[26]

In this regard, one of the most important heralds of both present and future innovation potential and economic transformation may be VC investment. VC backed firms are roughly three to four times more innovative (as measured by their patent production) than their counterparts that receive

other forms of private investments and as it happens clean economy companies are increasingly in the sights of VCs.[27] Between 1995 and 2010, the share of U.S. VC dollars flowing to clean economy concerns increased from 2 percent in 1995 to 16 percent in 2010.[28] Looking forward, analysts predict increasing shares of global and U.S. VC investment to flow into clean economy technologies.[29]

Even now the pace of innovation has picked up in many clean economy sectors, and with it the possibility that the clean economy will create future jobs as well as new climate-friendly goods, services, and processes. On this front, patenting tells the story. According to the Organization for Economic Cooperation and Development (OECD), patent applications filed at the European Patent Office (EPO) related to the clean economy rose from 4.6 percent of all patents in 1987 to 7.4 percent in 2007, such that by 2007, over 9,000 clean economy patent applications were being filed annually, just at the EPO. Some 17 percent of these patents originated with U.S. inventors.[30]

In short, the clean economy increasingly looks like a promising location for the emergence of significant new technologies, processes, and industries that will shape the next economy and generate new jobs. That dozens of the world's nations ranging from Brazil and China to South Korea and Turkey are investing heavily in such development both reinforces the emerging consensus and underscores that the "race to clean" has become an urgent competition among states for the resource productivity, jobs, and export-oriented manufacturing that will come with it.[31]

The metropolitan clean economy matters because that's where the clean economy is being built, firm by firm and cluster by cluster.

But why, then, does the metropolitan or regional clean economy matter inordinately? The reason has to do with the special importance of geography in economic life.

Regions contain, aggregate, and amplify the key "drivers" of innovation and economic dynamism.[32] Far from being placeless, the economy–and economic change–is place-based. In this respect, the clean economy–like the rest of the economy–is neither disembodied nor "flat," but concentrates in particular places.[33]

This concentrated reality of the national and the clean economies is first of all arithmetic. Just as the 100 largest U.S. metropolitan areas encompass two-thirds of the nation's population but three-quarters of the nation's economic output, such places contain and add up key pluralities of the nation's clean economy markets and inputs.

The largest 100 metros contain, for example, 66 percent of the nation's population, 63 percent of the nation's residential structures, and 64 percent of the nation's vehicle miles traveled while accounting for 56 percent of the nation's carbon emissions.[34] As such, these regions represent the nation's prime users of public water, electricity, and fuel; stand as the core generators of wastes and pollution that must be remediated; and so represent a prime global market for air and water management, energy efficiency goods and services, building retrofits, renewable energy, low-carbon transportation solutions, and the smart systems needed to run them. Already, 73 percent of the nation's LEED certified green buildings stand in the nation's top 100 metro areas.[35]

More than major markets for clean economy goods and services, however, the nation's largest metro areas aggregate the key inputs to clean innovation. Two-thirds of the nation's major research universities and environmental science and energy doctorate programs reside within the 100 largest metropolitan areas as do three-quarters of the nation's workers with degrees in science and engineering.[36] Likewise, 48 out of nation's 83 top environmental sciences and energy research laboratories operate there.

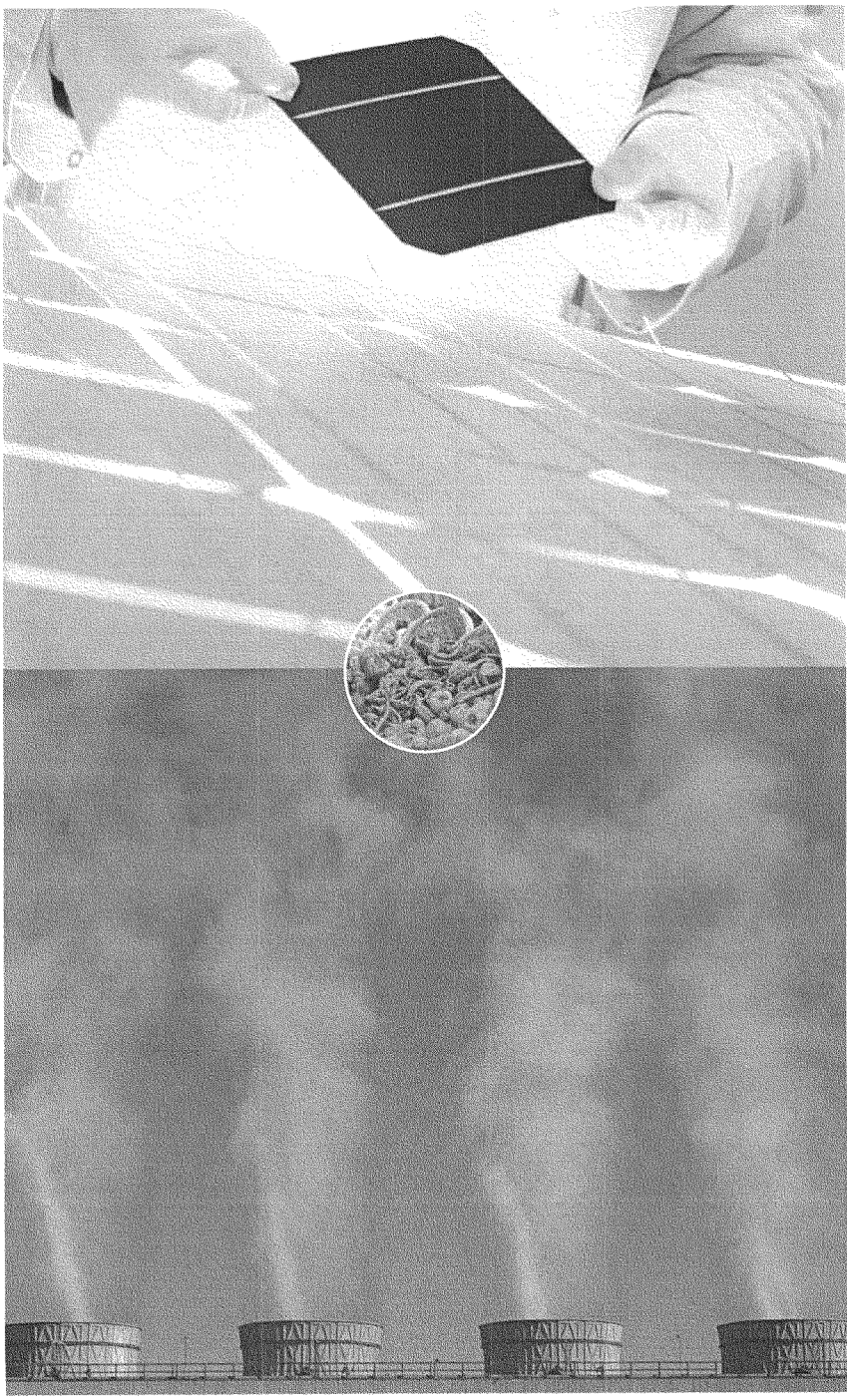
At an early stage of the commercialization pathway, no fewer than 96 of the 119 companies and research organizations that have so far won grants from the Advanced Research Projects Agency–Energy (ARPA-E) for cutting-edge clean energy research projects are based in the largest U.S. metros.[37] Farther along the path, Department of Energy (DOE) loan guarantees have also flowed heavily to metropolitan centers of commercial activity and deployment. Some 86 percent of this financing has flowed to the 21 projects (out of 30 total) located in the 100 largest metro areas.[38] On the environmental side, 65 percent of Small Business Innovation Grants administered by the Environmental Protection Agency flowed to the top 100 metros.

These results reinforce U.S. economic geography. The 100 largest metropolitan areas are the nation's innovation engines, generating some 78 percent of the nation's green patents.[39] Their dynamism, moreover, means that 54 of the 58 highest-impact U.S. cleantech firms called out in the 2010 Global Cleantech 100 list are based in the 100 largest U.S. metropolitan areas. (Going further, 39 of the 58 are headquartered in just four metros characterized by vibrant clean economy industry clusters–Boston, San Francisco, San Jose, and Los Angeles).[40]

In short, metropolitan areas, large and small, are now and will increasingly be the nation's critical centers of clean economy talent, innovation, and finance and so its top hubs of commercialization, deployment, and trade.

Regions and metropolitan areas, in short, are not a part of the national clean economy; they *are* that economy, as Alan Berube has written.[41]

For all of its significance, though, rather little is known about the size and shape of the clean economy, especially at the regional level. "Sizing the Clean Economy" is one response to that gap. ❀



DEFINING AND MEASURING THE CLEAN ECONOMY IN U.S. METROPOLITAN AREAS

Whatever the terminology, the "clean" or "green" or low-carbon economy prompts almost as much confusion as it does curiosity and fascination. One reason: Defining it and measuring it have proven extraordinarily difficult.

Literally hundreds of disparate studies of the clean or green economy exist. In fact, the California Employment Development Department requires 24 pages in a recent digest to list all of the studies it tracks on the clean economy.[1] Many of these studies focus on individual states. Others create national data using various methods. And many of the analyses employ varied definitions of this heterogeneous sphere of economic activity. For their part, the state- or region-specific studies provide detailed information but usually can't be compared across geographic units to place states or metropolitan areas in the national context. At the same time, the national studies either ignore sub-national geography or only provide information at a very high level of aggregation.

Hence, what follows is the first study of the U.S. clean economy to provide consistent and timely information that is both comprehensive enough in its scope and detailed enough in its categorization to inform national, metropolitan, and even local leaders on the recent dynamics of the U.S. low-carbon and environmental goods and services super-sector–with particular emphasis on regional growth and evolution.

Similarly, the pages that follow extend a large body of work at the Brookings Metropolitan Policy Program on the nature of the emerging "Next Economy" in the United States.[2] This work has focused on the possible underpinnings of future U.S. growth and moved to investigate the contention that the "next" U.S. economy needs to be more export-oriented, lower-carbon, and innovation-driven as well as opportunity rich. Key methodological decisions in developing this report were made with those preoccupations in mind. Further details are available in a detailed methodological appendix that is available separately from this report at the "Sizing the Clean Economy" project page on the Brookings website (http://www.brookings.edu/metro/clean_economy.aspx).

DEFINITIONS AND CATEGORIES

While there is no consensus on a definition of the clean economy, there are many points of agreement. Moreover, various studies have openly and thoughtfully addressed the difficulties involved. In advancing a definition of the clean economy, therefore, this report seeks to align itself with well-established guidelines and precedents while laying out rules that are simple, internally consistent, transparent, and replicable.

The basic definition of the clean economy used in this study runs as follows:

The clean economy is economic activity–measured in terms of establishments and the jobs associated

with them—that produces goods and services with an environmental benefit or adds value to such products using skills or technologies that are uniquely applied to those products.

To elaborate on this relatively succinct and conservative definition, a few words are in order on the precedents, terms, and approach employed here.

First, it bears noting that the language and distinctions used here draw heavily from both European and U.S. government statistical precedents. Most notably, key aspects of the present definition, categorization, and approach draw from previous definitional and measurement work by Eurostat and the Organization for Cooperation and Development (OECD) as well as by the U.S. Environmental Protection Agency (EPA) and the U.S. Bureau of Labor Statistics (BLS), which will next year release its own measurement of the "green" economy.[3] In that sense this measurement has sought continuity with other authoritative research rather than newness.

Second, it is also worth noting that this is an economic development study focused tightly on clean economy business establishments and the jobs they create. To elaborate on this orientation, this report is primarily about the establishments and jobs of U.S. enterprises whose products have an environmental benefit, including those that add value as part of the clean economy supply chain. Given that, the report does not attempt to measure jobs in companies that conduct themselves in an environmentally-friendly manner. Rather, it insists that companies and establishments sell, or in the case of the public sector, provide products or services with an environmental benefit (either inherently, like environmental remediation services or relatively, like organic food or solar panels). For example, no effort was made here to count companies that adopt internal environmental goals, re-form their processes to make them more environmentaly responsible, or even contribute to general public knowledge about environmental issues. However valuable these activities are, this study excludes the jobs related to those activities from the clean economy. They could be thought of as "clean process" jobs, as opposed to "clean production" jobs.[4]

As stipulated above, moreover, a product must benefit the environment to be deemed "clean." This is consistent with the BLS standard for its clean production survey, and it is a slight variation on the Eurostat standard which mandates an environmental purpose.[5] The environmental benefits include preventing or minimizing pollution (including greenhouse gas emissions), or natural resource depletion, or managing natural resources, including energy, air, and water, for greater efficiency, conservation, or protection.

The last part of the above definition—regarding companies that add value to clean economy products—is intended to capture the relevant aspects of the clean supply chain. Companies that directly produce clean technologies or services, like wind turbines, are unambiguously part of the clean economy, but it is less clear how to classify companies that supply parts or services to those clean producers, such as manufacturers of parts for turbines. Some suppliers provide products that are used across industries and purposes (e.g. screws, computer equipment, accounting, financial management), but others make products that are only used in the clean technologies or require skills that are unique to clean technologies (e.g. blades, frames, environmental engineering). The guiding principle used in this study has been to only include the establishments of companies that add value uniquely to clean products, whether by supplying a special part or a service, using skills or technologies that are unique to the clean economy. For example, home weatherization, energy retrofitting, and solar panel installation require skills that distinguish those services from traditional maintenance work or roofing.

Finally, some industry and impact studies estimate "direct" and "indirect" employment. By contrast, this study measures only employment in establishments that directly produce goods and services with environmental benefits, or produce uniquely tailored goods and services that add value to products with an environmental benefit. Studies of "indirect" jobs, for their part, use information on cross-industry purchases to claim that one industry stimulates the creation of jobs in another. This method is useful for regional impact studies that estimate the effect of business relocations and national impact studies that estimate the effect of government stimulus during a downturn. In both cases, the source of added revenue can be thought of as external and temporary. However, such an approach is not appropriate for a study like this one where there is no external source of revenue. No establishment generates its own revenue out of nothing, and so every direct job is some other industry's indirect job.

Consequently, the job totals reported here will be lower than many studies which include "indirect" jobs. This isn't to deny that clean economy firms are involved in rich networks of business relations with traditional "non-clean" firms; it is simply to say there is no reason to think of these general suppliers or customers as components of the clean economy sector.

This approach has the advantage of being firmly rooted in economic activity connected to supply and demand in competitive markets, rather than just voluntary business philanthropy. This focus, along with a "direct" jobs count from actual companies, makes the measurements akin to industry data from government agencies and provides the sort of straightforward information needed for strategic thinking about investments.

MEASUREMENT AND DATA

With the definition and method settled, the Brookings-Battelle team proceeded to measure the clean economy by building a database of clean economy companies and establishments "from the ground up." That is, instead of doing a national survey, which would be extremely costly if it were to be locally representative and require an array of difficult assumptions about sampling, the team took on the task of identifying and locating every company (and ultimately establishment) in the clean economy that could reasonably be identified using a variety of validated public and proprietary data sources.

Normally, standard industrial codes would be used for such a measurement exercise, but because the clean economy pervades so many industries, many codes contain establishments that fall both inside and outside the clean economy while at the same time no existing industry classification system breaks out green industries, whether it be solar energy activities, energy efficient products, green materials production, or enterprises aimed at the reduction of greenhouse gases. Or as the BLS explained in its March 16, 2010 Federal Register notice on approaches to measuring the green economy: "The studies reviewed showed that neither of the standard classification systems used in the BLS data, the North American Industry Classification System (NAICS) or the Standard Occupational Classification (SOC), identifies a green or environmental grouping of industries or occupations."

The upshot: Company and ultimately establishment-specific information was needed to identify and quantify clean economy establishments and employment.

Identifying clean economy companies and establishments

Two approaches were taken to identify clean economy firms. First, a set of industries deemed exclusively part of the clean economy was identified using the eight-digit SIC (Standard Industrial Classification) system developed by the business intelligence firm Dun & Bradstreet (D&B) and maintained as a time series by Walls & Associates as the National Establishment Time Series (NETS).[6] In performing research on the clean economy for the Pew Charitable Trusts, Collaborative Economics developed a list of industries that could be considered completely embedded in the clean economy, in that each establishment in that listing produces goods or services that have an environmental benefit as defined above. More recently, Berkeley researchers worked off that list and added over 100 new SICs to it.[7] This study used the Berkeley list as a starting point and incorporated almost every company, establishment, and job in those industries and added relevant SICs for air, water, waste management and treatment.[8] This industry-based approach yielded 49 percent of all jobs and 69 percent of all establishments included in this study (see external appendix for full list).[9]

The second approach employed for identifying clean economy firms and establishments was to create a validated master clean economy list to catalogue every known industry association, certification, federal grantee, venture capital recipient, patent assignee, and product list that is relevant to the clean economy. In this fashion, over 60 lists of clean economy companies (see the appendix) were compiled to create a substantial list of firms. The team also considered and incorporated listings from market research organizations and proprietary industry data sources, such as the Environmental Business Journal and Plunkett's Renewable, Alternative and Hydrogen Energy Industry Almanac. All of the lists were carefully validated. Lists were rejected if the team discovered that non-clean economy companies were allowed to join. The companies from the master list were incorporated into the study, and duplicate establishments were removed.

With the industry codes identified and firm lists assembled, the next step was to find statistics on the companies and their relevant establishments using Dun & Bradstreet. Establishment history and other characteristics were added through the use of NETS.

For companies that produce both "green" and "non-green" products an effort was made to include only establishments that specialize in the clean economy production. This task was facilitated by Dun & Bradstreet and NETS because they employ detailed industry classification schemes that distinguish activities across establishments of the same company and even within single locations.

For cases where large establishments were known to produce both green and conventional products, information from companies, including their websites, was used to allocate a percentage of the site's employees to the clean economy based on the relative importance of its clean products compared to all of its products. Because of the nature of the Dun & Bradstreet database, many of the smaller establishments of less than five employees were a mix of independent contractors and field offices rather than stand-alone establishments. In order to ensure consistency within the establishment and job count, those very small establishments were excluded from the Brookings-Battelle database. This resulted in a roughly five percent reduction in the total number of clean economy jobs and a larger reduction in the number of establishments as most of them had zero jobs. (See appendix for details).

Classifying the establishments

Once the company, establishment, and job information was compiled, the next step was to classify it. The goal was to make the data as analytically useful as possible to facilitate research at various geographic levels and especially for regional economic development planning. There were a number of options, and ultimately this study reports the data in three ways.

First, through Dun & Bradstreet and NETS, the data is organized by NAICS categories, which is how the U.S. government reports data (e.g. for manufacturing, construction, financial services, and so on). Second, because only a small fraction of NAICS categories reside within the clean economy, a second scheme was adopted that divided establishments into five high-level categories (largely adopted from the BLS). Finally, to provide a third, finer-grained categorization, 39 segments designed by the Brookings-Battelle team was used to further narrow the class of business activity and allow for detailed analysis.[10] Establishments were assigned to segments based on their industry code, the list used to identify them, or, in some cases, information provided by the company's website.[11] The external methods appendix presents a table that shows how the company lists were matched up to segments.

Other measures

A series of other measures were created using the clean economy database. Details on how these were calculated are available in the appendix document. A quick description follows:

Because of the way companies were identified–using member lists, grantee lists, and so on–no way existed for recreating the same universe of clean economy firms in previous years. Yet, the employment history of firms currently existing–including when they were born–was available through NETS from 2003 to 2009 (with D&B data providing the most current 2010 jobs figures–as downloaded in early 2011). This created a problem when calculating **growth rates**: The base year was artificially higher than it would otherwise be because the database contained no record of job losses from establishments that went out of business (only those that laid off workers). This is fine when comparing segments, states, or MSAs, because the bias is shared more or less evenly, but it won't work for comparisons against the "non-clean" national economy. To adjust U.S. growth from 2003 to 2010 for the loss of jobs from closing establishments, information was obtained from the Bureau of Labor Statistics' Business Employment Dynamics series and the NETS.[12] The national base year

Table 1. Brookings-Battelle Clean Economy Industry Categories and Segments

Brookings-Battelle Category	Brookings-Battelle Detailed Segments
Agricultural and Natural Resources Conservation	Conservation Organic Food and Farming Sustainable Forestry Products
Education and Compliance	Regulation and Compliance Training
Energy and Resource Efficiency	Appliances Battery Technologies Electric Vehicle Technologies Energy-saving Building Materials Energy-saving Consumer Products Fuel Cells Green Architecture and Construction Services HVAC and Building Control Systems Lighting Professional Energy Services Public Mass Transit Smart Grid Water Efficient Products
Greenhouse Gas Reduction, Environmental Management, and Recycling	Air and Water Purification Technologies Carbon Storage and Management Green Building Materials Green Chemical Products Green Consumer Products Nuclear Energy Pollution Reduction Professional Environmental Services Recycled-Content Products Recycling and Reuse Remediation Waste Management and Treatment
Renewable Energy	Biofuels/Biomass Geothermal Hydropower Renewable Energy Services Solar Photovoltaic Solar Thermal Waste-to-Energy Wave/Ocean Power Wind

could then be adjusted to calculate what growth would have been nationally if no jobs were lost from establishments that closed. The job growth figures reported in this report reflect this adjustment, and therefore are higher than actual net growth rates.

Exports from each establishment were estimated by allocating national exports for a given three or four-digit NAICS industry to establishments based on the establishment's share of total U.S. employment in that three or four-digit industry. A similar approach was applied to metropolitan areas in recent Brookings research and is described in detail in that report.[13] The same sources and techniques were used here.

Data on the number of **occupations**, type of occupations, **wages**, and education requirements for each job were calculated using national statistics from the BLS's Occupational Employment Statistics (OES) program and Employment Projections Program (EPP).[14] OES provides estimates for the number and type of occupations in each four-digit NAICS, and EPP provides education attainment estimates for each occupation. Occupations that fell within the middle range of the median wage distribution were classified as moderate-wage "green collar" pursuits.

Establishments were identified as **clustered** if they were located in a county with a significant number of jobs in other establishments in the same segment. The threshold was whether or not the number of other-establishment jobs in a county's segment was greater than one percent of the U.S. jobs for that the segment. Other definitions–including the use of relative shares–yielded similar results.

LIMITATIONS AND CHECKS

While the goal of this report was to measure every establishment and job in the clean economy, that is clearly an impossible task. The study surely left out many companies that are rightfully part of the clean economy, and there is no doubt that the employment figures and location data from Dun & Bradstreet and NETS will not always exactly match the real world.

One reason for this is the fact that for whatever reason some clean economy companies fail to appear on any of the lists used to compile the bulk of the database.

Take the car-sharing business, for example, which claims to reduce the demand for cars and the consumption of gas through its convenience and fuel-efficient car-sharing fleets.[15] These assertions are supported by academic research on car-sharing.[16] Critics could counter that car-sharing encourages driving over more environmentally-friendly public transportation, and there is evidence that car-sharing

is more common where public transit is readily available.[17] But whatever its true environmental impact, no car-sharing company is in this database. The reason is that they did not win any clean economy grants, join any green industry associations, obtain any green certifications, develop any clearly identifiable green economy patents, or receive money from a cleantech venture fund. There are surely other companies that many people would consider to be "green" that likewise did not make it into this database for the same reason.

With these caveats in mind, there is compelling evidence that the Brookings-Battelle clean economy database provides a reasonably accurate estimation of the clean economy.

To assess and improve accuracy, a preliminary version of this database was shared with research partners with regional expertise in metropolitan areas like Sacramento, Chicago, the counties of the Northeast Ohio region, and the states in New England. The research partners were asked to identify, by their judgment, mistakes in the database including, especially, clean economy firms that were left out of the Brookings-Battelle database. Some of these research partners embarked on extensive efforts of data collection, including interviews with local industry leaders and analysts. Where significant oversights or discrepancies were identified the Brookings-Battelle team redoubled its efforts to locate new lists with broader coverage of those sectors that were originally under-counted. The resulting effort added several hundred thousand jobs to the database. This process was repeated on several occasions.

To get a general sense of the accuracy of the final database, one can compare it to other studies of the clean economy. In this fashion, the Brookings-Battelle database contains 2.7 million jobs. This figure runs to the higher end of recent estimates but lies within the range reported by the U.S. Department of Commerce in a recent report. For that matter it is three to five times higher than national estimates produced in recent years by the Pew Charitable Trusts and the U.S. Conference of Mayors.

At the state level, the number of clean economy jobs reported in this count tends to slightly exceed that reported by various state survey estimates. The present count runs between 12 and 25 percent higher than the total number of jobs estimated by state government surveys in Oregon, California, and Connecticut.[18] Estimates by a state agency for Washington in 2008 were roughly half of the Brookings-Batelle estimates but after a methodological change the 2009 edition of the survey yielded a jobs number 19 percent higher than the Brookings-Battelle estimates.[19] Two states—Missouri and Kansas—came up with "direct job" estimates that were one-third to one-fourth lower than the Brookings-Battelle figures.[20] Michigan was the only state with a major green jobs survey that produced a substantially higher number than the Brookings-Battelle employment estimate.[21] There, the Brookings-Battelle estimate came in about 30 percent lower than the Michigan number. Finally, a study of 11 large counties in California by researchers at the University of California at Berkeley located 110,000 clean economy jobs in those counties—a figure that compared with a Brookings-Battelle figure of 169,000 for the same counties.[22]

Finally, the Brookings team also compared job levels in this database to various industry reports. In almost every case, the industry reports—which frequently reported "indirect" as well as "direct" jobs—exceeded the present estimates. However, when direct jobs are compared, the Brookings numbers are much closer. The Solar Energy Industries Association has estimated 24,000 direct jobs in the solar industry.[23] This number is slightly lower than the 29,531 estimated by Brookings and Battelle. The Solar Foundation, in conjunction with Green LMI, did a national survey suggesting that there were 93,502 solar energy jobs (mostly in California) but only 24,916 jobs in solar manufacturing.[24] This comparison reveals that the Brookings-Battelle estimates probably undercount jobs in solar installation; those workers are difficult to measure because the work is done by companies that are heavily involved in traditional construction and installation activities. For its part, the National Hydropower Association estimates that hydropower accounts for 60,000 direct jobs, compared to 55,433 estimated by Brookings-Battelle.[25] Likewise, the American Wind Energy Association estimates 30,000 direct jobs; Brookings-Battelle estimates 24,294 wind jobs.[26] And finally, the Geothermal Energy Association estimates 9,000 direct jobs, while the Brookings-Battelle figure is 2,720.[27] Overall, while not perfect matches, these comparisons suggest the database presented here is fairly reliable, though coverage of solar installers is probably lacking.

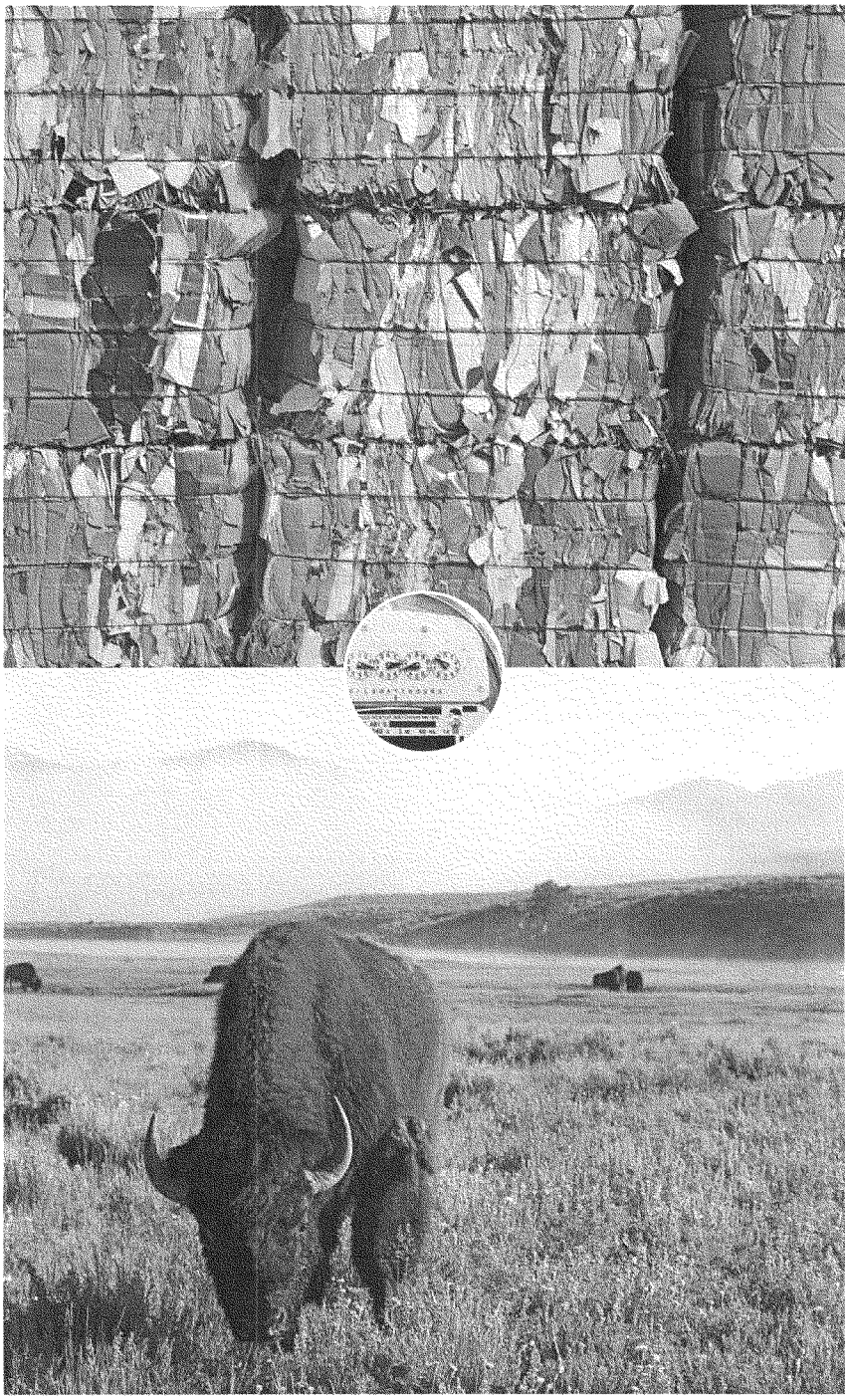
To gauge how well the database picked up specific companies, a final quality check was conducted using the Global Cleantech 100 list produced by *The Guardian* newspaper in partnership with Cleantech Group. These 100 highly-rated companies were selected by a panel of 60 experts from around the world under the criteria that the companies represent the highest potential for market impact, are for-profit and private, and are not listed on any major stock exchange.[28] Of these, 81 percent (or 47 out of 58) were included in the Brookings-Battelle database. Those missed were either not covered by Dun & Bradstreet or had fewer than five employees in the D&B record; the only exception was a car-sharing company, which did not make it on to any public list except the Global Cleantech 100.

In short, through comparisons with other national, regional, and even industry studies and refined lists of new firms like those on the Global Cleantech 100, the evidence suggests that the Brookings-Battelle method offers a reasonably accurate measure of the clean economy. National and state comparisons provide no evidence that this method has significantly undercounted the number of clean economy jobs. Indeed, most studies of comparable geographies have found many fewer jobs, and yet, the strict requirements for inclusion mean that an over-count is highly improbable.

In addition to accuracy, the "bottom-up" method utilized here makes this arguably the most comprehensive study to date. No other dataset provides such fine-grained classification and no other dataset provides national, state, and metropolitan data across the entire United States. What is more, while the forthcoming BLS green jobs study will provide some of these geographic advantages (state data will be available), it will probably not be able to disclose job numbers in many locations because of survey-participation agreements. Likewise, it will report the data at the two-digit NAICS level but will not offer the segment detail provided in the Brookings-Battelle database.

Ultimately, the two surveys should prove complementary. While the BLS survey will be valuable, it may not fully satisfy the demand from state and metropolitan actors for detailed geographic and segment information, which means existing sub-national measurement efforts, such as this study, will probably need to be continued as long as there is interest in measuring the clean economy.

In conclusion, while many studies of the green or clean economy have often seemed to play out as proxy wars in the larger debate over climate change policy, this work tries to step back from those issues. By embracing sound precedents and transparency, this effort seeks simply to deliver a reasonably accurate and locally useful measurement of the firms, establishments, and jobs in the United States that are providing goods and services related to protecting the environment, mitigating climate change, conserving energy, and generating clean power. The sections that follow analyze the data and discuss various policy implications. At the same time, for those who want to drill down on all of the jobs data, as well as selected clean economy indicators for the nation, the states, and the 100 largest metropolitan areas, that material is available for free download at the Brookings website (http://www.brookings.edu/metro/clean_economy.aspx).



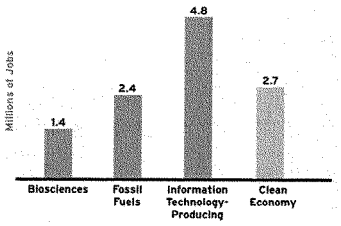
IV. MEASURING AND TRACKING THE CLEAN ECONOMY IN U.S. METROPOLITAN AREAS

So what does this assessment of the U.S. clean economy find? This analysis of establishment-level data compiled by the Metropolitan Policy Program at Brookings and Battelle covering the entire United States and focusing on the nation's 100 largest metropolitan areas reveals a series of key takeaways:

1. The clean economy, which employs some 2.7 million workers, encompasses a significant number of jobs in establishments spread across a diverse group of industries. In 2010, 2.7 million jobs in the United States directly contributed to the production of goods and services that had an environmental benefit. The jobs were spread over 57,501 different establishments in 41,185 companies and existed in almost every industry.

Encompassing 2 percent of all positions, the clean economy represents a modest slice of the U.S. economy. By contrast, the healthcare sector—the nation's largest source of private employment—employs 13.8 million workers, and accounts for 10.2 percent of jobs.[1] Yet, compared to many other cross-industry sectors, the clean economy looks much more significant (see Figure 1). For example, just 1 percent of jobs (1.3 million) directly support the production of fossil fuel-based energy, derivative manufactured products, and machinery; that number rises to 1.8 percent (2.4 million) if all wholesale and retail distributors and transporters are included such as gas station employees.[2] Likewise, the biosciences sector—a focus of much investment interest—supports just 1.4 million employees.[3] Producers in the

Figure 1. The Clean Economy Compared with Other Sectors of the U.S. Economy



Source: Biosciences: Battelle and Biotechnology Industry Organization, "State Bioscience Initiatives 2010" (2010); Fossil Fuels: Brookings analysis of County Business Patterns and Bureau of Labor Statistics data; Information Technology: Moody's Analytics; Clean Economy: Brookings-Battelle Clean Economy Database The job levels reported here reflect data from multiple years: Biosciences from 2008; Fossil fuels from 2009; and the remainder from 2010.

Table 1. Segments of the Clean Economy

Category	Segment	Jobs, 2010
Agricultural and Natural Resources Conservation	Conservation	314,983
	Organic Food and Farming	129,956
	Sustainable Forestry Products	61,054
Education and Compliance	Regulation and Compliance	141,890
	Training	266
Energy and Resource Efficiency	Public Mass Transit	350,547
	Energy-saving Building Materials	161,896
	HVAC and Building Control Systems	73,600
	Green Architecture and Construction Services	56,190
	Professional Energy Services	49,863
	Appliances	36,608
	Energy-saving Consumer Products	19,210
	Battery Technologies	16,129
	Smart Grid	15,987
	Electric Vehicle Technologies	15,711
	Lighting	14,298
	Water Efficient Products	13,066
	Fuel Cells	7,041
Greenhouse Gas Reduction, Environmental Management, and Recycling	Waste Management and Treatment	386,116
	Professional Environmental Services	141,046
	Recycling and Reuse	129,252
	Green Consumer Products	77,264
	Green Building Materials	76,577
	Nuclear Energy	74,749
	Recycled-Content Products	59,712
	Remediation	56,241
	Air and Water Purification Technologies	24,930
	Green Chemical Products	22,622
	Pollution Reduction	9,986
	Carbon Storage and Management	391
Renewable Energy	Hydropower	55,467
	Wind	24,294
	Solar Photovoltaic	24,152
	Biofuels/Biomass	20,680
	Solar Thermal	5,379
	Waste-to-Energy	3,320
	Geothermal	2,720
	Renewable Energy Services	1,981
	Wave/Ocean Power	371

Source: Brookings-Battelle Clean Economy Database

important information technology (IT) sector do employ more workers than the clean economy—approximately 4.8 million—but almost one third of those jobs are in wholesale and retail.[4]

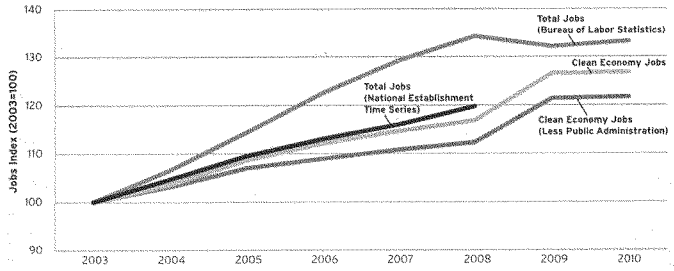
In terms of its sectoral profile, the clean economy encompasses a wide variety of activities that extends far beyond high-profile renewable energy and energy efficiency sectors. In fact, the vast majority of clean economy jobs produce goods or services that protect the environment or reduce pollution in ways that have little to do with energy or energy efficiency. Nearly one-fifth of clean economy jobs, for example, involve agriculture and conservation, which includes a variety of land and forestry management jobs, as well as those in organic farming. Another 40 percent of clean economy jobs benefit the environment through greenhouse gas (GHG) reduction, the management of resources like air and water, and recycling. Businesses involved in renewable energy, by contrast, comprise just 5 percent of all clean economy jobs. Nuclear energy, considered clean but non-renewable, comprises 3 percent of jobs: roughly 75,000.

Getting into more detail, the largest single segment of the clean economy involves waste management and treatment, which employs nearly 400,000 workers—14 percent of all clean economy jobs. Here, the U.S. Bureau of Reclamation is the largest employer, followed by the waste management and water operations of the city of Los Angeles and the city of New York. The second largest segment is public mass transit, which employs another 350,000 workers and yields an environmental benefit by displacing single-passenger vehicles. First Student Inc., a nationwide school bus operator (which displaces less efficient personal-vehicle travel), is the largest single employer in transportation, followed by the National Railroad Passenger Corporation (known as Amtrak), and the operators of the dense Northeast corridor: the Long Island Railroad and the New York and Washington, DC metropolitan transit authorities. The third largest segment is conservation, a substantial number of workers in which are employed by the U.S. Fish and Wildlife Service, the U.S. Forestry Service, and National Park Service, as well as state and local governments.

Despite their small size, meanwhile, the activities most strongly identified with the clean economy may be renewable energy production and energy-saving technologies. The largest renewable segments are hydropower, wind energy, and solar photovoltaic (PV) energy, which provide about three-quarters of all renewable energy jobs, or just over 100,000 jobs. Large firms in these segments include General Electric, Rosendin Electric, and Vestas in wind and MEMC Electronic Materials, First Solar, and Sharp in solar. Other energy-focused segments include fuel cells, smart grid, battery technologies, and electric vehicles, with many small, young firms, as well as large companies like Ball Aerospace & Technologies and 3M, key players in fuel cells; Itron and Black & Veatch Corp in smart grid; and Exide Technologies and Delphi in batteries. These segments provide some 55,000 "direct" jobs.

The rest of the green economy, finally, involves

Figure 2. Clean Economy Job Growth Compared with Overall Job Growth, Excluding Establishments That Closed, 2003-2010



Source: Brookings-Battelle Clean Economy Database, National Establishment Time Series (NETS), and the Bureau of Labor Statistics

Clean economy data was only available for establishments that were in business in 2010 and therefore data for prior years do not reflect jobs losses due to establishment closings. To be comparable, the total U.S. jobs data presented here from NETS are only for establishments that were in business in 2009, as NETS data for 2009 and 2010 was not available to the study. The total U.S. jobs data from BLS presented here were also adjusted to account for job losses due to establishment closings. To make the adjustment, the number of job losses in future years up until 2010 was subtracted from total employment in the base year, using data from the Business Employment Dynamics program.

everything from regulation and compliance (such as the EPA's activities), to research and engineering (enterprises like Oak Ridge National Lab), green architectural services, building products, and more. Over 77,000 clean economy jobs, for example, can be found in companies that make a diverse array of "green" consumer products, or those with environmentally sustainable ingredients. This includes companies–such as L'Oreal, Maybelline, Pfizer, and Johnson and Johnson–whose products have received high environment marks from the GoodGuide, an independent consumer products rating enterprise.[5]

Yet beyond these categories and segments there is one more way to think about the clean economy and that is in terms of the era of the environmental concern being addressed. In this respect, over 90 percent of clean economy jobs lie in older segments that provide goods or services that solve long-appreciated environmental problems. Many of these jobs reside in government but others populate commercial segments like lighting, water efficient products, green building materials, recycling and reuse, and pollution reduction. At the same time, though, a newer layer of establishments has emerged that is working on other environmental problems, the dangers of which have only recently been widely understood–such as global warming and the side effects of fossil fuel production. They are doing so through the creation of new forms of energy, as well as energy saving, storage, and mitigation products.

2. The clean economy grew more slowly in aggregate than the national economy between 2003 and 2010 but newer "cleantech" segments far outperformed the nation during the period, as did the clean economy overall during the recession. Overall, today's clean economy establishments added more than half a million jobs between 2003 and 2010, expanding at an annual rate of 3.4 percent. This performance somewhat lagged behind in the national economy, which grew by 4.2 percent annually over the period (if job losses from establishment closings are omitted to make the data comparable).[6] And yet, during the middle of the recession–from 2008 to 2009–the clean economy grew faster than the rest of the economy, expanding at a rate of 8.3 percent. This is likely due, in part, to the American Recovery and Reinvestment Act (ARRA), which channeled large sums of public spending towards clean energy projects through much of 2009.

In interpreting these numbers, the reader should keep in mind that the Brookings-Battelle database lacked any information on establishments that died (i.e. closed) before 2010, but was able to get establishment history for those enterprises operating in 2010 and identified as part of the clean economy. Therefore, all the clean economy job growth figures reported in this report are higher than they would otherwise be since, for example, jobs that existed in 2003 at an establishment that closed in 2005 would not have been captured by our searches in 2010–to the effect of lowering the job count in 2003. To make the data comparable, U.S. growth data is adjusted similarly, removing job losses from establishment deaths. This was done using data from NETS (through 2008) and the Bureau of Labor Statistics' Business Employment Dynamics series (through 2010). (Figure 2).

Which layers of the clean economy grew fastest? Young establishments in a few key segments drove most of the job growth. Excluding closings, 78 percent of all job gains between 2003 and 2010 came from establishments born in 2003 or later. Most new jobs are created by new enterprises across the broader economy, too, but the impact per establishment is not as marked as in the clean economy.[7] There, only 22 percent of all establishments were created in or after 2003 and yet they generated that large majority of the job creation.[8] To put this in perspective, old establishments in the clean economy (those born before 2003) created an average of just three jobs for every one establishment from 2003 to 2010 while new establishments created 37 jobs. This compares favorably to new establishments nationally which created just 10 jobs per establishment over the same period (excluding job losses from deaths).[9] The takeaway: Young establishments in the clean economy had a substantially greater job creation impact per establishment than their "non-clean" peers in the national economy.

Which segments grew fastest? Again, the youngest did. The 13 segments in which the bulk of establishments date to later than 1996 grew by 8.3 percent annually from 2003 to 2010–a figure that easily outstripped the 3.2 percent growth of older segments as well as the 4.2 rate for the national economy over the same period (Table 2).

Along these lines, four of the five fastest-growing segments during this seven-year period were in renewable energy. Solar thermal grew at a torrid pace, expanding by 18.4 percent annually over the seven years and adding

Table 2. Job Growth and Median Year of Establishment Birth by Clean Economy Segment

Segment	Absolute Change in Jobs, 2003-2010	Annual Average Change in Jobs, 2003-2010 (%)	Median Year of Establishment Birth
Wave/Ocean Power	+273	20.9	2005.5
Solar Thermal	+3,732	18.4	2001
Wind	+15,110	14.9	2004
Carbon Storage and Management	+228	13.3	2002
Solar Photovoltaic	+12,286	10.7	2005
Fuel Cells	+3,499	10.3	2000
Biofuels/Biomass	+9,296	8.9	2004
Smart Grid	+7,001	8.6	1999.5
Conservation	+121,147	7.2	1996
Professional Energy Services	+18,702	6.9	2001
Professional Environmental Services	+51,793	6.8	1996
Geothermal	+998	6.7	1998
Green Architecture and Construction Services	+19,678	6.4	1989
Renewable Energy Services	+687	6.3	2002
Electric Vehicle Technologies	+5,447	6.3	2001.5
Regulation and Compliance	+46,826	5.9	1995
Recycling and Reuse	+39,668	5.4	1993
Remediation	+15,539	4.7	1996
Air and Water Purification Technologies	+6,858	4.7	1993
Public Mass Transit	+82,601	3.9	1989
Waste-to-Energy	+754	3.7	1990
Waste Management and Treatment	+79,401	3.3	1994
HVAC and Building Control Systems	+14,946	3.3	1993
Energy-saving Building Materials	+25,985	2.5	1993
Organic Food and Farming	+15,025	1.8	1987
Nuclear Energy	+7,813	1.6	1994
Battery Technologies	+1,524	1.4	2002
Green Building Materials	+7,081	1.4	1989.5
Recycled-Content Products	+3,237	0.8	1992
Green Consumer Products	+232	0.0	1992
Sustainable Forestry Products	-4,299	-1.0	1992
Pollution Reduction	-1,038	-1.4	1992
Lighting	-1,971	-1.8	1992
Energy-saving Consumer Products	-4,405	-2.9	1993
Appliances	-9,063	-3.1	1989
Green Chemical Products	-6,173	-3.4	1992
Hydropower	-16,158	-3.6	1990
Water Efficient Products	-9,189	-7.3	1992
Training	+266	N/A*	1989
Aggregate Clean Economy	**+565,337**	**3.4**	**1995**

**The training segment had zero jobs in 2003*

Source: Brookings-Battelle Clean Economy Database

3,700 jobs. The wind power industry added 15,000 jobs, growing 14.9 percent per year. Solar PV added 12,286 jobs with 10.7 percent average annual growth. Moreover, biofuels, another renewable segment, added 9,300 jobs with 8.9 percent growth each year over the period.

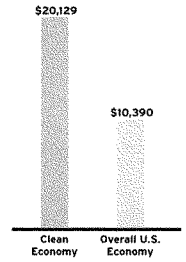
Young, technology-heavy segments were also adding jobs at elevated rates each year over the period. For example, establishments involved in fuel cell production created roughly 3,500 jobs while those working in smart grid added 7,000, with annual growth of 10.3 and 8.6 percent respectively.

The slowest growing segments, by contrast, saw job losses from establishment contractions overwhelm job gains from expansions and openings. Many of these losses took place in older building- and building infrastructure-related segments that were evidently hurt by the housing-centered recession, including, for example: water efficient products (e.g. plumbing and bathroom equipment); green chemical products (house paint); appliances; and energy-saving consumer products (office equipment, glass, home weatherization services). Hydropower and nuclear energy also experienced weak growth, with the former actually losing jobs.

3. The clean economy is manufacturing and export intensive. Manufacturing and exporting are strengths of the clean economy. Engaged in the production of everything from house paint to fuel cell components and refrigerators, approximately 26 percent of all clean economy jobs are involved in manufacturing, compared to just 9 percent of jobs in the economy as a whole.[10] In addition, Brookings estimates that in 2009 clean economy establishments exported an estimated $49.4 billion in goods, representing 5.3 percent of all U.S. goods exports. Such establishments were also responsible for an additional $4.5 billion in service exports.

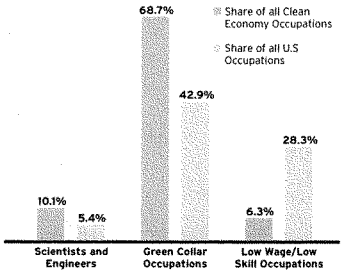
Manufacturing, for its part, accounts for a majority of the jobs in over half of the clean economy segments: 20 to be exact. Several segments—including electric vehicle technologies, water efficient products, green chemical products, appliances, sustainable forestry products, lighting, recycled-content products, and energy-saving consumer products—are particularly manufacturing intensive, with roughly 90 percent or more of their jobs residing in manufacturing establishments. Both solar-related segments, along with wind energy, have more than two-thirds of their jobs in manufacturing. Even the organic food and farming segment is largely comprised of manufacturing

Figure 3. Exports Per Job in the Clean Economy Versus the Overall U.S. Economy, 2009



Source: Brookings-Battelle Clean Economy Database; Brookings analysis of United States International Trade Commission, Bureau of Economic Analysis, and Moody's Economy.com data

Figure 4. Occupations in the Clean Economy, 2010



Source: Brookings-Battelle Clean Economy Database and U.S. Bureau of Labor Statistics Occupational Employment Statistics and Employment Projections Program

establishments involved in food processing.

Moreover, the share of all manufacturing jobs engaged in clean economy production is on the rise. From 2003 to 2010, clean manufacturers added 35,832 jobs (excluding closings), while U.S. manufacturers overall laid off 3.3 million workers.[11] Clean economy manufacturing employment expanded at a rate of 0.8 percent each year (or 5.5 percent over the entire period); meanwhile, U.S. manufacturers at large shed jobs at a rate of 1.5 percent per year (for a growth rate of -10.1 percent over the period). Again, both of these rates exclude jobs losses from establishments that closed over the period, since that data was not available for the clean economy.

Manufacturing frequently is linked to exporting, meanwhile, and so it is in clean economy. In fact, on a per job basis, the clean economy is about twice as export-oriented as the national economy. To be precise, Brookings estimates conclude that some $20,129 worth of exports is sold for every job in the clean economy, compared to just $10,390 in exports for the average U.S. job.[12] The most export-oriented segment–on an exports per job basis–is biofuels, which generates an estimated $189,000 in exports per job. This is followed by green chemicals, electric vehicle technologies, wind, battery technologies, solar PV, fuel cells, air and water purification technologies, and recycled-content products, which export roughly $63,000 per job.

These export estimates were calculated by Brookings based on the NAICS industry of each clean economy establishment. The external methods appendix document discusses the methodology in more detail.

4. The clean economy offers more opportunities and better pay for low-skilled workers than the national economy as a whole. Another strength of the clean economy is the access it affords to decent jobs up and down the skills ladder. Typical wages in the clean economy exceed those in the aggregate U.S. economy by roughly 13 percent, based on an analysis of the dataset. The median wage of a typical clean economy job approaches $44,000. This figure far exceeds the compensation level of the typical job in the United States. The national median wage is just $33,190 (or $38,616 if calculated using a weighted average of the medians, as was done for the clean economy).

This should not be interpreted to mean that clean economy firms are somehow more generous towards their workers, which may or may not be true. Indeed, previous research suggests that clean producers act like other companies in whatever industry they occupy.[13] Rather, as the methods section and external methods appendix describes, these wage statistics were estimated based on the (four-digit NAICS) industry group, which generated occupational estimates and finally wages. In other words, the better pay reflects the fact that the clean economy jobs are in better paying industries with better paying occupations.

In fact, a large majority of jobs in the clean economy are middle-wage "green collar" occupations defined here as those having a median wage that falls within 20 percentage points of the national median wage of $33,190 ($26,552 to $39,828). Of the 22 major occupational groups defined by the Bureau of Labor Statistics, the six that fall below this range are classified as low wage/low skill occupations, the seven that fall within it as middle wage/middle skill, and the nine above it as high wage/high skill occupations (see Appendix E).

As Figure 4 shows, more than two-thirds of all clean economy jobs fall within this middle-wage "green-collar" category, compared to 43 percent of jobs in the broader economy (see data appendix for details). This middle-wage clean economy orientation reflects the large number of installation and construction occupations in the sector (these are over 1.5 times more prevalent in the clean economy than in the national one) as well as its tilt toward occupations in production and transportation (which are over twice as prevalent in the clean economy). As a complement to the clean economy's middle-income occupational profile, numerous technical occupations populate the sector. Along these lines, the clean economy employs a higher percentage of scientists, architects, and engineers (10.1 percent) than the national economy (5.4 percent) and a much lower percentage of workers in the worst-paying occupations such as food preparation, sales, and healthcare support. Overall, just 6.9 percent of clean economy jobs lie in the lowest paying occupations while 28.3 of U.S. jobs fall into this tier.

There is also one more attractive feature of the clean economy opportunity structure: The clean economy not only pays well, but pays well even for those without post-secondary degrees. Almost half of all jobs in the clean economy are held by workers with a high school diploma or less, compared to only 37.2 percent of U.S. jobs. These clean economy jobs–many of which are in "green collar" occupations involved in making and moving products–provide higher wages than typical "low-skill" jobs: Approximately 28.1 percent of all occupations in the clean economy are strong-wage (paying above the U.S.

Table 3. Share of Clean Economy Jobs That Are Green Collar by Segment, 2010

Segment	Share of Jobs That Are Green Collar (%)	Share of Jobs That Require a Diploma or Less (%)
Public Mass Transit	90.3	54.4
Green Building Materials	85.3	61.1
Recycled-Content Products	85.0	58.1
Sustainable Forestry Products	83.7	60.1
Energy-saving Building Materials	81.6	58.7
Green Consumer Products	78.9	55.4
Remediation	78.7	52.9
Electric Vehicle Technologies	78.1	53.7
Appliances	77.8	54.0
Waste-to-Energy	76.6	49.4
Waste Management and Treatment	76.4	46.6
Recycling and Reuse	75.4	51.3
Wind	75.1	49.8
Geothermal	73.6	46.8
Water Efficient Products	72.9	50.2
Green Chemical Products	72.8	48.9
Lighting	71.4	49.6
Energy-saving Consumer Products	71.4	49.2
Solar Thermal	70.8	53.3
Hydropower	68.8	37.5
Air and Water Purification Technologies	67.9	47.6
Biofuels/Biomass	67.1	45.3
Solar Photovoltaic	66.7	45.0
Nuclear Energy	66.0	36.7
HVAC and Building Control Systems	65.2	45.0
Organic Food and Farming	65.1	59.5
Battery Technologies	64.0	44.9
Renewable Energy Services	63.6	40.5
Regulation and Compliance	59.1	29.0
Carbon Storage and Management	55.3	38.4
Conservation	50.6	27.1
Training	50.3	40.2
Smart Grid	48.2	33.4
Fuel Cells	46.1	33.9
Pollution Reduction	41.4	31.0
Green Architecture and Construction Services	32.9	26.0
Professional Environmental Services	26.7	20.2
Professional Energy Services	26.2	20.5
Wave/Ocean Power	23.0	19.6

Source: Brookings-Battelle Clean Economy Database and Bureau of Labor Statistics

median) and low-skill (the percentage of workers with a high school diploma or less is higher than the national average) compared to 13.3 percent in the national economy. Conversely, only 32.5 percent of clean economy jobs are weak-wage (paying below the U.S. median) and low-skill, compared to 41.4 percent nationally. Table 3 shows how green collar occupations and education requirements vary across segments.

5. Among regions, the South has the largest number of clean economy jobs though the West has the largest share relative to its population. Turning to the geography of the clean economy, it turns out that almost one-third of all clean jobs are located in the U.S. South. The West comes next with nearly one-quarter of these jobs, followed by the Midwest with 23 percent and the Northeast with 20 percent. Measured as a percentage of total employment, the West commands the largest relative share, as 2.2 percent of the region's jobs are in the clean economy. The Northeast also manages to beat the national average for its percentage of jobs in the clean economy (2.1 percent), followed by the Midwest (2.0 percent) and the South (1.8 percent).

In terms of absolute employment numbers, California clean economy establishments lead the nation by providing 318,156 jobs, well over 100,000 more jobs than in the next largest state, New York, whose establishments support 185,038 jobs. Texas (144,081) is third and four more states register six-digit employment levels. Impressively, seven southern states tally at least 50,000 jobs in the clean economy. These states include Florida, Georgia, North Carolina, Tennessee, Virginia, and South Carolina.

Turning to the relative size of each state's clean economy, half of the 10 states possessing the highest job shares in the clean economy are in the West. Alaska has the largest total share of its jobs in the clean economy (4.7 percent), the majority of which involve conservation and management of the environment given the state's massive parklands. Oregon (3.4 percent) is a big producer of organic food, as well as green building materials and sustainable forestry products; Montana contains vast public lands with park rangers and related professions but also jobs in solar PV and hydropower. Washington and Idaho also fall into the top ten. Yet much of West's advantage on clean intensity comes from its historic possession of national parklands. In terms of private activity, the West has a slightly lower share of jobs in the clean economy than the Northeast and Midwest. Alaska, Montana, and Idaho fall out of the top ten. Vermont, with a disproportionate number of jobs in organic food and farming, as well as green building materials, has the highest private-sector clean economy job share (as a percentage of total state employment) at 2.6 percent; Oregon remains second and Wisconsin moves up to fourth, with a strong showing in water efficient products, sustainable forestry products, recycled-content products, various building and appliance related segments, battery technologies, and fuel cells.

6. Most of the country's clean economy jobs and recent growth concentrate within the largest metropolitan areas. Focusing now on metropolitan geography, some 84 percent of all clean economy jobs resided in the nation's metropolitan areas in 2010; some 64 percent congregated in the largest 100 metros alone. That supermajority falls slightly short of the 66 percent share of the nation's population living in those metros but the gap is closing: Large metros' share of clean economy jobs has increased by 3.3 percentage points (from 60.5 percent) since 2003. All told, three-quarters of clean economy jobs created from 2003 to 2010 were created in large metros.

Some clean economy segments are more "metro-centric" than others, however, and this concentration has been highly correlated with job growth.

To the first point, the varying degrees of segment concentration in large metros are noteworthy. For example, the largest 100 metros contain over three-quarters of the jobs in some 13 clean economy segments that include, starting with the most concentrated: training, professional energy services, architecture and construction, renewable energy services, waste-to-energy, wind, professional environmental services, battery technologies, smart grid, solar PV, and mass transit. By contrast, eight segments have fewer than half of their jobs in the 100 largest metropolitan areas. These include farming and resource-oriented activities such as hydropower, sustainable forestry products, and biofuels.

Turning to the association of metro concentration with growth, the story is even more striking. Looking at the years 2003 to 2010, the segments that started the period as more concentrated in metros grew significantly faster—roughly 1.7 percentage points faster annually for every 10 percentage point increase in the share of jobs in large metros. None of the five slowest-growing segments over the period—water efficient products, hydropower, green chemicals, appliances, and energy-saving consumer products—were disproportionately concentrated in large metros in 2003. By

Table 4. Metro Areas with the Most Clean Economy Jobs, 100 Largest Metros, 2010

Metro Area	Clean Economy Jobs	Clean Share of All Jobs (%)
New York-Northern New Jersey-Long Island, NY-NJ-PA	152,034	1.8
Los Angeles-Long Beach-Santa Ana, CA	89,592	1.7
Chicago-Joliet-Naperville, IL-IN-WI	79,388	1.8
Washington-Arlington-Alexandria, DC-VA-MD-WV	70,828	2.3
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	54,325	2.0
San Francisco-Oakland-Fremont, CA	51,811	2.7
Atlanta-Sandy Springs-Marietta, GA	43,060	1.9
Boston-Cambridge-Quincy, MA-NH	41,825	1.7
Houston-Sugar Land-Baytown, TX	39,986	1.6
Dallas-Fort Worth-Arlington, TX	38,562	1.3

Source: Brookings-Battelle Clean Economy Database and Moody's Analytics

A Diversified Portfolio: Atlanta's Clean Economy

Atlanta-Sandy Springs-Marietta is the most diverse metropolitan area clean economy in the nation. Its approximately 43,000 clean economy jobs are very evenly spread across the 39 segments of the clean economy. With this breadth and depth, Atlanta–the seventh largest metro clean economy in the country–is well positioned to be a major hub in a variety of clean activities.

Even with that diversity, two export-oriented segments are highly clustered–in that employees at one establishment are surrounded by a substantial number of workers at other establishments in the same segment. These segments are green architecture and construction services–with major firms like Heery International, Winter Construction, and tvsdesign; and smart grid–led by GE, USI Energy, and Ista, amongst others. Across these segments, Atlanta has 5,605 jobs spread over 26 establishments.

The region also has another 8,332 jobs from 59 establishments in six moderately clustered segments: recycled content products (Rock-Tenn, Rehrig Pacific); green building materials (Shaw Industries); water efficient products (Toto); green chemical products (Arch Chemical, Sherwin-Williams); battery technologies (Exide and Enrev); and appliances (Hill Phoenix).

This wide presence across segments has helped make Atlanta a clean economy contender. Its growth performance has been solid–21st out of the 100 largest metros from 2003 to 2010. But more importantly perhaps, the median age of its establishments is just 12 years, making the Atlanta clean economy the sixth-youngest in the nation, among the 100 largest metros. This entrepreneurial dynamism, along with its diversity, bodes well for its future.

Source: Brookings-Battelle Clean Economy Database

contrast, of the five fastest-growing segments from 2003 to 2010, only the tiny carbon storage and management segment (which employs technologies like carbon capture and sequestration) started off the period with fewer than 70 percent of its jobs in one of the 100 largest metropolitan areas.

The connection between fast growth and metro concentration is not surprising, meanwhile. As discussed in Chapter II, large metros disproportionately claim many of the assets and resources companies need to succeed, such as educated workers, infrastructure, top-research universities, and venture capital financing.[14] Likewise, younger, more dynamic companies often start in large metros before moving out to less populated areas, once their production techniques are refined, to take advantage of lower costs.[15]

7. The clean economy permeates all of the nation's metropolitan areas but it manifests itself in varied configurations. In this respect, the clean economy exists in every region, in part because of the ubiquity of such basic clean economy activities as wastewater management, public transit, and environmental regulation. And yet, for all of its pervasiveness, the clean economy varies widely in size and shape. Most notably, because many of its companies are exporters and have adapted to varied market and policy dynamics, the clean economy is spread unevenly across U.S. metropolitan areas.

Employment levels and segment diversity

In terms of population, **New York** and **Los Angeles** are the nation's largest metropolitan areas. Accordingly, they also possess the most clean economy jobs: 152,000 and

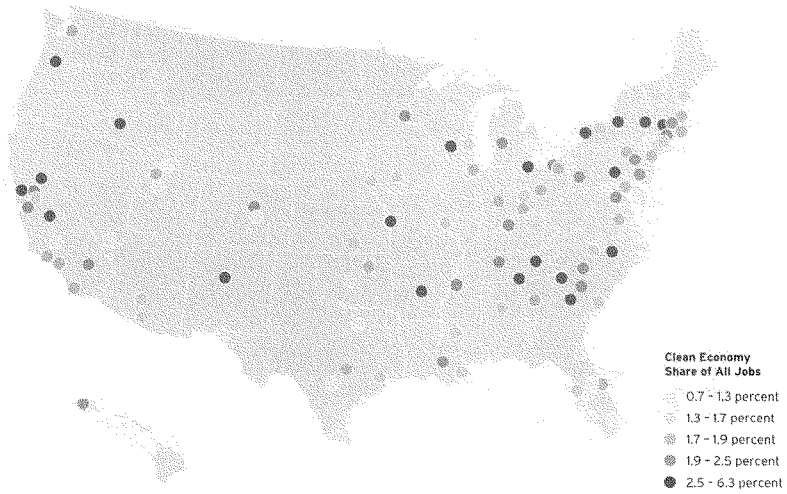
In short, the measurements and trends reviewed here offer a mixed picture of a diverse array of industry segments that is in many places **making significant progress despite a very difficult economic** and policy environment.

Table 5. Metro Areas with the highest share of clean economy jobs, 100 Largest Metro Areas, 2010

Metro Area	Clean Economy Jobs	Clean Share of All Jobs (%)
Albany-Schenectady-Troy, NY	28,087	6.3
Knoxville, TN	16,135	4.9
Sacramento--Arden-Arcade--Roseville, CA	37,319	4.5
Harrisburg-Carlisle, PA	13,025	4.0
Toledo, OH	11,831	3.9
Springfield, MA	10,443	3.5
Madison, WI	12,337	3.5
Little Rock-North Little Rock-Conway, AR	11,934	3.4
Greenville-Mauldin-Easley, SC	10,127	3.4
Raleigh-Cary, NC	16,677	3.3

Source: Brookings-Battelle Clean Economy Database and Moody's Analytics

Figure 5. Clean Economy Intensity in the 100 Largest Metro Areas, 2010



Source: Brookings-Battelle Clean Economy Database and Moody's Analytics

89,600, respectively. **Chicago** comes in third with 79,388. **Washington** has the fourth most clean economy jobs with 70,828, followed by **Philadelphia** and **San Francisco**, each with over 50,000. **Atlanta**, **Boston**, **Houston**, and **Dallas** round out the top 10.

These large metros have very different profiles. **New York** and **Washington** are uniquely specialized in public-goods providing segments. In the former, over 50 percent of the metro's jobs come from public mass transit and waste management and treatment. In Washington, roughly 48 percent of the jobs come from conservation and regulation and compliance activities. By contrast, in nine highly diversified metros, including **Atlanta**, **Boston**, **Dallas**, and **San Francisco**, less than 30 percent of the metros' jobs reside in the two largest segments.

Generally, large metros are extremely diversified in their segment concentrations, meaning that the share of clean economy jobs coming from each segment is relatively small. This is especially true of **Atlanta**—the most diverse clean economy with strengths in segments like smart grid, water efficient products, appliances, and architecture—but also **Milwaukee**, **Boston**, **Seattle**, and **San Francisco**. **Milwaukee** is strong in water efficient products and batteries; **Boston** establishments are disproportionately represented in such varied domains as improved coal technology, waste-to-energy, solar PV activities, pollution reduction, HVAC and building control systems, fuel cells, and professional environmental services. **Seattle's** jobs cut across renewable energy services, green architecture, smart grid, and forestry products. For its part, **San Francisco** is a center for smart grid development but specializes as well in temperature control equipment, solar PV, electric vehicles, architecture, environmental research, solar thermal, and remediation.

Assessed by their orientation to the clean economy (measured by clean jobs as a share of total jobs), many of the clean economy's regional focal points are mid-sized

Leading the Way: Albany's Clean Sweep

With a higher concentration of clean jobs than any other major metro area in the country, Albany-Schenectady-Troy, NY is a surprise leader in the clean economy.

Nearly one in 15 Albany area workers–over 28,000 people–make their living in the clean economy. Two major players stand out in driving the capital region's outsize performance: General Electric (GE) and the state government.

GE, for its part, still locates a number of critical and growing clean economy operations in its birthplace of Schenectady, including: its global renewable energy headquarters, its power and water division headquarters, and a wind and water turbine manufacturing facility. GE's advanced battery research center–the only U.S. Department of Energy-designated Energy Frontier Research Center led by a private company–completes the conglomerate's striking clean economy presence in the region.

As the capital of the third-most populous state, meanwhile, New York's "Capital District" contains another 10,500 jobs in public sector-oriented segments like regulatory and compliance and conservation too.

Yet Albany's clean economy has a richness extending beyond these two major players that hints at the emergence of a robust cluster. Over 4,000 scientists and engineers complement a concentration of over 6,000 manufacturing workers. Nearly 4,000 individuals spread across a network of 33 establishments provide professional energy and environmental services. And a solid industry presence fortified by an institutional research emphasis exists in the fuel cells segment.

Recent activity in the region's thick network of academic institutions and public-private partnerships bodes well for the region's clean economy future. The New York state Energy Research and Development Agency's (NYSERDA) energy and environmental technology energy incubator, ICLEAN, is maturing and its parent, the College of Nanoscale Science and Engineering (CSNE) at the University of Albany, has since its establishment in 2004 emerged as a global leader in semiconductor and nanotech research–technologies that drive "cleantech." For its part, the Rensselear Polytechnic Institute hosts the New York State Center for Future Energy Systems, which along with NYSERDA's activities, leverages the region's position as the state capital to establish a central node in a state-wide, cross-disciplinary, market-oriented clean economy knowledge network.

Sources: Brookings-Battelle Clean Economy Database, College of Nanoscale Science and Engineering website; General Electric Company press releases, January 21, 2011; February 1, 2010; May 19, 2009.

metros. They include six state capitals, which is largely a function of the outsized role played by the public sector in maintaining environmental health. The **Albany** region, for example, has the largest share of local jobs (6.3 percent) in the clean economy of any large metro nationwide. As both a state capital and a home to GE dating back to Thomas Edison's tenure, it has a massive presence in wind-related activities, battery technologies, professional energy services, fuel cell development and production, and regulation and compliance–its largest segment. It is also over-represented in hydropower, remediation, conservation, and environmental research among others.

Among clean economy intensive locales, Albany is followed by **Knoxville**, with 4.9 percent of its jobs in the clean economy, and then two state capital regions, **Sacramento** and **Harrisburg**, which have clean jobs that stand at 4.5 and 4.0 percent, respectively, of total jobs. With over half of its jobs coming from just one segment–professional energy services–**Knoxville** has one of the least diversified clean sectors in the nation, largely because Oak Ridge National Laboratory has such a major presence. As the seat of a large state government, **Sacramento's** clean economy is largely composed of the public conservation and regulatory sector, and yet it also has a strong presence in professional environmental services, recycling, and public mass transit. **Harrisburg** is similarly weighted towards the public sector but as home to Three Mile Island also has a large number of jobs in nuclear power.

Toledo and **Madison** represent the Midwest in the top 10 most clean-oriented major metros, while **Greenville, SC**; **Little Rock**, and **Raleigh** comprise the strong southern contingent. Toledo has the third-highest percentage of private sector jobs in the clean economy, at 3.7 percent. Solar PV is a leading segment along with fuel cells, battery technologies, regulation, green chemicals, green consumer products, solar thermal, and nuclear energy. **Greenville, SC** is similar to Albany in its strength across a number of clean technologies, including wind, electric vehicles, lighting, and water efficient products. **Little Rock** gathers a large number of jobs in green consumer products as well as electric vehicles, while **Raleigh** has a disproportionate number of jobs in training, smart grid, pollution reduction, regulation, and architecture and construction services. **Chattanooga**, finally, as another strong southern performer, has over 1,000 jobs in each of three major sectors–green building materials, nuclear energy, and hydropower–while housing a smaller but still disproportionate coterie of jobs in geothermal, battery technologies, and wind.

Employment growth

Employment growth also ranges widely. In 53 of the nation's 100 largest metros, establishments in the clean economy added jobs at a faster clip than those outside of it from 2003 to 2010.[18] Clean economy establishments in **Knoxville**, **Raleigh**, **Des Moines**, and **Little Rock** registered the fastest growth of all large metros with annual growth rates above 10 percent. Growth in **Knoxville** was fueled by the professional energy services segment and Oak Ridge National Laboratory. In **Raleigh**, job expansions were largely attributable to the government and public transit segments, with small contributions from smart grid and a few others. In **Des Moines** too, the public sector, via conservation, drove growth, along with waste management. On the other hand, green consumer products provided the bulk of job growth in **Little Rock**. For **Albany**, which had the fifth-fastest growing clean economy among large metros, gross job expansions were almost evenly shared between regulation and compliance and the region's strong wind presence.

On the opposite end, **Grand Rapids** lost clean economy jobs most quickly from 2003 to 2010. Even excluding potential job losses from closing establishments, it lost 9.1 percent of its clean economy workforce annually (a loss of nearly 50 percent over the entire period). Much of this came from thousands of layoffs in green consumer products. These devastating losses were only somewhat offset by solid job gains in the HVAC and building controls systems segment and organic farming and food processing. **San Jose**, surprisingly, considering its innovation prowess, was ranked 95th amongst large metros on job growth in the clean economy from 2003 to 2010. Massive losses–adding up to thousands of jobs in lighting and energy-saving consumer products–outweighed the substantial job gains in the wind and solar PV segments. Job losses in **New Orleans's** non-tradable segments–namely public mass transit and waste

Table 6. Metro Areas with the Fastest and Slowest Clean Economy Job Growth, 100 Largest Metros, 2003-2010

Metro Area	Clean Economy Jobs, 2003	Clean Economy Jobs, 2010	Average Annual Change, 2003-2010 (%)	Average Annual Change (Less Public Administration), 2003-2010 (%)
Knoxville, TN	6,206	16,135	14.6	14.6
Raleigh-Cary, NC	6,788	16,677	13.7	11.4
Des Moines-West Des Moines, IA	2,472	5,256	11.4	2.4
Little Rock-North Little Rock-Conway, AR	5,916	11,934	10.5	9.9
Albany-Schenectady-Troy, NY	15,557	28,087	8.8	6.0
Ogden-Clearfield, UT	1,184	2,111	8.6	6.1
McAllen-Edinburg-Mission, TX	1,243	2,203	8.5	7.2
Tulsa, OK	4,076	7,130	8.3	5.4
Toledo, OH	6,873	11,831	8.1	8.5
Albuquerque, NM	5,851	9,912	7.8	4.3
Columbia, SC	8,099	8,568	0.8	1.4
El Paso, TX	2,570	2,695	0.7	0.3
Buffalo-Niagara Falls, NY	13,952	14,452	0.5	-0.3
Milwaukee-Waukesha-West Allis, WI	13,516	13,471	0.0	-0.2
San Jose-Sunnyvale-Santa Clara, CA	19,360	18,868	-0.4	-1.0
Modesto, CA	2,974	2,688	-1.4	-2.3
New Orleans-Metairie-Kenner, LA	8,385	7,298	-2.0	1.4
Augusta-Richmond County, GA-SC	9,110	6,106	-5.6	-5.8
Palm Bay-Melbourne-Titusville, FL	6,204	3,446	-8.1	-13.5
Grand Rapids-Wyoming, MI	17,232	8,812	-9.1	-9.4

Source: Brookings-Battelle Clean Economy Database

Table 7. Metro Areas with the Highest and Lowest Exports per Job in the Clean Economy, 100 Largest Metros

Metro Area	Clean Economy Exports (millions of 2009 dollars)	Clean Economy Jobs, 2010	Exports Per Job, 2009
Greenville-Mauldin-Easley, SC	$872.4	10,127	$86,143
Little Rock-North Little Rock-Conway, AR	$686.4	11,934	$57,514
Albany-Schenectady-Troy, NY	$1,239.0	28,087	$44,114
Memphis, TN-MS-AR	$467.7	11,515	$40,621
Grand Rapids-Wyoming, MI	$349.2	8,812	$39,631
San Jose-Sunnyvale-Santa Clara, CA	$726.8	18,868	$38,521
Louisville-Jefferson County, KY-IN	$531.9	14,447	$36,817
Charleston-North Charleston-Summerville, SC	$151.2	4,369	$34,605
Cleveland-Elyria-Mentor, OH	$830.7	24,664	$33,682
Cincinnati-Middletown, OH-KY-IN	$554.3	18,525	$29,922
McAllen-Edinburg-Mission, TX	$12.7	2,203	$5,759
New Orleans-Metairie-Kenner, LA	$40.9	7,298	$5,604
Palm Bay-Melbourne-Titusville, FL	$19.2	3,446	$5,568
Honolulu, HI	$47.8	9,269	$5,161
Sacramento--Arden-Arcade--Roseville, CA	$185.7	37,319	$4,975
Virginia Beach-Norfolk-Newport News, VA-NC	$46.8	9,594	$4,883
Ogden-Clearfield, UT	$9.8	2,111	$4,657
Youngstown-Warren-Boardman, OH-PA	$13.1	2,977	$4,402
Springfield, MA	$42.6	10,443	$4,079
Colorado Springs, CO	$5.4	1,934	$2,770

Source: Brookings-Battelle Clean Economy Database and Brookings analysis of United States International Trade Commission, Bureau of Economic Analysis, and Moody's Economy.com data

management—could be attributed to decreased demand from population declines. These losses were not fully offset by gains in remediation and professional environmental services.

Exports

Turning to exports—domestically produced goods or services sold to foreign markets—the clean economy exhibits a distinctive geographic pattern. Older clean exporting establishments tend to be located outside of large metros, while newer fast-growing ones tend to be located inside them.

On the one hand, the nation's clean economy export activity occurs most intensively in locations outside the nation's 100 largest metros, which produce just 55 percent of U.S. clean exports despite containing 65 percent of the population. According to Brookings estimates, the three segments that generate the most exports by value are green chemicals, biofuels/biomass, and organic food and farming. These are all disproportionately non-metropolitan.

And yet, much of what is exported from outside of these large metros appears to be long-standing, more traditional commodities rather than new technologies–with the exception of biofuels. Approximately two-thirds of *growing* exporters, on the other hand, are located in one of the 100 largest metropolitan areas.[17] The newer exporting clean economy, therefore, is disproportionately happening in and around the nation's largest cities.

What metros export the most? With an estimated $2 billion of clean economy exports per year, **Chicago** is the nation's largest metropolitan exporter of clean technologies, goods, and services. The metro has seven segments that export over an estimated $100 million per year, the largest of which is energy-related professional services. Most of this segment's $500 million in annual exports are from a single large diversified company that does, among other things, energy efficient engineering research in the petro-chemicals industry. HVAC and building control systems is the second largest exporting segment in Chicago, followed by biofuels, green consumer products, air and water purification technologies, green chemicals, and organic food.

Los Angeles, **New York**, **Albany**, and **San Francisco** also contribute over $1 billion per year each to the clean export economy. **Los Angeles's** leading exports are in organic food, green building products, green consumer products, recycled-content products, and water efficient products. **New York's** exports consist largely of green consumer products, organic food, professional environmental services, and recycled-content products. In **Albany**, wind energy dominates. **San Francisco** exports clean products from a more diverse group of segments, including HVAC and buildings control systems, professional energy services, and electric vehicles.

Greenville and **Little Rock** also emerge as surprisingly strong exporters, both falling in the top 15 on total value of exports. Moreover, they are the two most export-intensive clean economies of all the large metros, based on the total value of exports per job. Roughly two-thirds of **Greenville's** clean economy exports are derived from wind turbine manufacture, but substantial contributions also come from electric vehicle technologies and building products. **Little Rock** also exports electric vehicles but derives most of its clean industry earnings from green consumer products, which grew robustly over the period. Other export-intensive metros include **Wichita**, a major exporter of biofuels; traditional manufacturing hubs like **Cleveland** and **Grand Rapids**; and logistic hubs like **Memphis**, **Louisville**, and **Cincinnati**.

Occupations

For every large metropolitan area except one (**Knoxville**), the majority of clean economy jobs reside in mid-wage "green collar" occupations, meaning those with moderate wages and moderate educational requirements in production, installation, maintenance, transportation, construction, social services, office support, or protective services. In 10 of the 100 largest metropolitan areas, moreover, these jobs represent at least three-quarters of all clean economy jobs based on Brookings estimates. Almost four out of five (78 percent) clean economy jobs fall in the green collar category in **Augusta, GA**, the nation's most "middle-job" oriented clean economy, with most of the relevant occupations lying in construction (26 percent of all occupation), and large shares in transportation (14 percent), office administration (13 percent), and production (13 percent). Other heavily green collar metros offer different configurations. Green collar jobs in **Dayton**, **Colorado Springs**, and **Salt Lake City** are heavily weighted towards transportation (26, 29, and 26 percent respectively). The largest share of **Louisville's** (37 percent) and **Chattanooga's** (27 percent) green collar jobs are in production.

Because green collar jobs are abundant within the clean economy and pay relatively well for their skill requirements, they arguably hold out the richest opportunities for low-skill workers in the clean economy. In fact, in every one of the 100 largest metros, the majority of clean economy jobs are available to workers without a college degree–and most are in mid-wage green collar occupations. **Modesto,** with a disproportionate number of jobs in organic food and farming, stands out with the highest share of jobs available to non-college graduates (82 percent). **Stockton** (81 percent) has a similar profile. **Augusta, GA** (81 percent), with high job shares in remediation and nuclear energy, is the second most non-college graduate-friendly clean economy. **Rochester** (81 percent) has a high percentage of jobs in public transportation. **Grand Rapids** and **Louisville**, by contrast, are heavily concentrated in the manufacturing segments like appliances. **Grand Rapids** also has large job shares in green consumer products and wind, while **Louisville** gets a large share from air and water purification technology.

At the other end of the spectrum, **Knoxville**, **Albany**, and **Harrisburg** offer the lowest percentages of clean economy jobs requiring less than a college degree amongst large metros (with shares of 56, 66, and 68 percent respectively). For **Harrisburg**, this is primarily due to the large public sector presence. For **Albany**, a large public sector and job concentrations in professional energy services and fuel cells raise educational and scientific skill requirements. **Knoxville**, in fact, has the highest percentage of science and engineering-related occupations amongst all large metros (34 percent). **Las Vegas**, with its many green architects is second on that measure (24 percent), while **San Francisco**–through architecture and professional services–is third (22 percent).

* * *

To put it all together, at least four rough types of regional clean economy can be discerned amid much variation and local distinctiveness. One sub-set of regional clean economies appears to be dominated by **services**–transportation, professional services, construction, administration, waste management, and remediation. These metros are more likely to have grown rapidly over the last seven years and include fast growers like Knoxville, San Diego, Hartford, Orlando, Honolulu, Las Vegas, and San Francisco. Another significant group of metropolitan clean economies appears heavily engaged in **manufacturing**. These metros had mixed growth rates–depending on the particular mix of their segments and specializations–but all export intensively and provide plentiful green collar opportunities. Among these metros reside numerous Midwestern and Southern metros such

Table 8. Metro Areas with the Largest Share of Clean Economy Jobs That Are Green Collar, 100 Largest Metros, 2010

Metro Area	Share of Clean Economy Jobs that are Green Collar (%)
Augusta-Richmond County, GA-SC	77.9
Dayton, OH	76.8
Louisville-Jefferson County, KY-IN	76.1
Chattanooga, TN-GA	75.8
Colorado Springs, CO	75.6
Rochester, NY	75.3
Salt Lake City, UT	75.3
Youngstown-Warren-Boardman, OH-PA	75.1
Stockton, CA	75.0
Cincinnati-Middletown, OH-KY-IN	74.9

Source: Brookings-Battelle Clean Economy Database and U.S. Bureau of Labor Statistics Occupational Employment Statistics and Employment Projections Program

An Emerging 'Blue' Innovation Hub: Milwaukee's Water Industry Cluster

The regional clean economy consists of much more than high-profile renewable energy or energy efficiency specializations. In metropolitan Milwaukee, the buzz surrounds water technology, as the region has recently emerged as a "blue" innovation hub with a high concentration of manufacturing and research in water efficient products, water purification technology, and waste management equipment and treatment.

In 2010, the Milwaukee metro region encompassed no fewer than 200 firms in the water industry that employed about 1,167 workers in the water efficient products segment alone—good for about 9 percent of all jobs in the U.S. in that segment, according to the Brookings-Battelle Clean Economy Database. From 2003 to 2010 the region saw a 23 percent increase in jobs in the "blue" sector with 39 percent of these jobs in companies that develop water efficient products and 13 percent in companies that produce water purification technologies. These companies develop a wide range of technologies that include equipment to measure and control the flow of water, emergency water supply, and drinking and waste water treatment equipment. Companies in the water efficient products and water purification technologies segments have on average about six establishments each in the metro region and have been producing groundbreaking building products to conserve water and energy that will help builders achieve LEED building certification.

Meanwhile, the cluster is gaining strength. Companies from outside the region are beginning to recognize the significance of Milwaukee's water innovation hub by moving to join it. American Micro Detection Systems, Inc., a California-based sensor technology manufacturer, located its first major operations in Milwaukee in July 2010 and Badger Meter relocated about 25 engineering professionals from its Oklahoma facility to Milwaukee in 2010. And for their part business and academic leaders in Milwaukee teamed up in 2009 to develop the Milwaukee Water Council to leverage the metro region's resources into an innovation cluster that can turn the next wave of water technologies into successful companies that have the potential for serious growth.

Sources: Brookings-Battelle Clean Economy Database; Dean Amhaus, Executive Director, Milwaukee Water Council, telephone interview, May 17, 2011; Milwaukee Water Council, "Overview of Milwaukee's World Water Hub;" "Milwaukee lands federal grant to develop water cluster," BizTimes.com, September 3, 2009; Milwaukee Water Council, "Executive Briefing," April 4, 2011.

as Grand Rapids, Greenville, Louisville, Memphis, Little Rock, and Cleveland, but also San Jose out West. On the other hand, the **public sector** supplies roughly half of clean economy jobs in state capital metros like Harrisburg, Sacramento, Raleigh, and Des Moines, helping these areas score highly on clean job intensity. Finally, a significant number of diverse metros exhibit fairly **balanced** profiles across the major industry groupings. This array of multi-dimensional clean economy centers includes Atlanta; Stockton; Portland, OR; Providence; Salt Lake; Detroit; and Los Angeles. In short, the clean economy pervades all of the nation's metropolitan areas but it manifests itself in many different configurations.

8. Strong industry clusters boost metros' growth performance in the clean economy. A final finding pertains to the role in economies of industry clustering—geographic concentrations of interconnected firms often accompanied by supporting or coordinating organizations. In this connection, it turns out that establishments in the clean economy add jobs markedly faster when they are located near peer establishments in the same county and same segment. To be precise, doubling the size of a clean economy cluster—the number of same-segment jobs in a county—increased job growth of establishments in the cluster by roughly 2.1 percent from 2003 to 2010, holding all else equal in a model tested here and discussed in the external methodological appendix.[18] In 2003, for example, jobs in clustered establishments represented 16.6 percent of all clean economy jobs. By 2010, that share increased to 19.0 percent.[19] These findings are consistent with volumes of academic work showing that clusters benefit economic performance in a variety of industries.[20]

The benefits of peer proximity are reinforced and magnified in large metros. The average clean economy establishment in a large metropolitan area is located in the same county as 1,130 other jobs in the same segment. By contrast, the county level of exposure to same-segment jobs was just 190 for clean economy establishments outside of the 100 largest metros. That difference in peer proximity is worth 5.5 percent higher job growth annually over the seven-year period ending in 2010, holding all else equal.[21] In this respect the clean economy is like most industries where new, fast-growing firms disproportionately emerge from large metro agglomerations.[22]

The findings above use a "continuous" definition of clusters based on the size of other establishments in the same segment. However, an alternative "binary" definition can be employed to compare clustered to isolated establishments. For these purposes, an establishment had to be located in the same county as at least 1 percent of national jobs in its segment to be considered clustered.

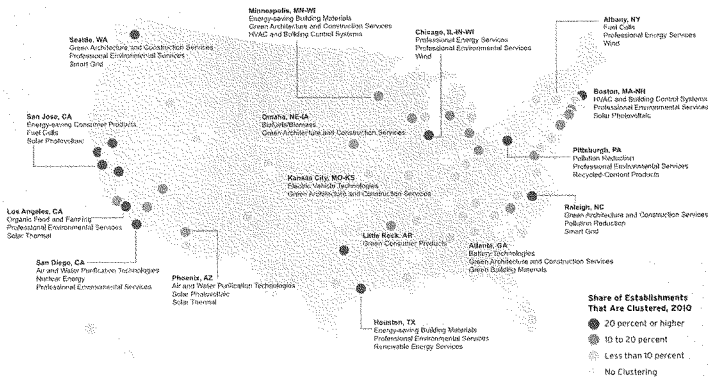
Other definitions were used, which obtained similar results, but the 1 percent definition proved to be the strongest predictor of job growth. With this definition, clustered establishments grew at a rate of 4.6 percent annually from 2003 to 2010, while isolated establishments grew at a rate of just 3.2 percent.[23] This definition gives larger counties an advantage but that advantage appears to be justified: As discussed in the external methods appendix, the benefits from clustering are robust to controls for county-size.

At the metropolitan level, the analysis was restricted to establishments in the tradable or export-oriented segments of the clean economy. This excluded all nine segments that export less than $4,000 per worker on average.[24]

In 13 of the largest 100 metropolitan areas, at least 20 percent of clean economy establishments are embedded in clusters—as defined above as proximity to at least one percent of U.S. jobs in an export-oriented segment. By that standard, **Houston** provides a clustered environment for 74 percent of its clean economy establishments—the highest percentage for the nation's 100 largest metropolitan areas. In fact, in nine of its segments, at least 75 percent of the establishments are clustered. These segments are: renewable energy services, geothermal, green architecture and construction services, professional energy services, energy-saving building materials, wind, professional environmental services, HVAC and building control systems, and biofuels/biomass. They range from as few as two establishments (in the small segment geothermal) to 123 (in professional environmental services).

Clean establishments in metropolitan **Los Angeles** are also exceptionally clustered, with 73 percent of establishments meeting the cutoff. Here, six segments are completely clustered: energy-saving consumer products, solar PV, pollution reduction, organic food and farming, green architecture and construction services, and professional environmental services. Another eight segments in Los Angeles cluster at least 75 percent of

Figure 6. Metro Area Establishment Clustering, 2010



Source: Brookings-Battelle Clean Economy Database
An establishment in a given segment is defined to be in a cluster if other establishments in the same county comprised at least one percent of all U.S. employment for the given segment.

establishments. **Seattle** is high on the list with 45 percent clustering, through professional energy services, green architecture and construction, professional environmental services, organic food and farming, sustainable forestry products, wind, and smart grid. Metropolitan **Pittsburgh**–with a clustering rate of 36 percent–has highly clustered segments such as professional environmental services, wind, pollution reduction, and solar thermal. The **Boston** metropolitan area clusters roughly 30 percent of its establishments in segments like fuel cells, green architecture and construction, solar PV, professional energy services, and energy-saving consumer products. By contrast, **Little Rock's** green consumer product makers are highly clustered while no other segment is.

Under this strict 1 percent definition of clusters, 37 large metropolitan areas completely lack clustered establishments. Many of these have location quotients above one for various segments–indicating a disproportionate number of jobs in the segment relative to the United States–but these jobs largely come from a single large establishment or are spread out in different counties within the metro. The metros have proven that they have the workforce, infrastructure, or business climate to sustain successful clean economy companies and yet they haven't been able to fully generate the benefits of a densely clustered network of similar firms in any one segment.

* * *

In short, the measurements and trends reviewed here offer a mixed picture of a diverse array of industry segments that is in many places making significant progress despite a very difficult economic and policy environment.

On the positive side, the data depict a modest-sized but widely distributed set of industries that already employ more people than the fossil fuels and biotech industries and which is already nearly half the size of the nation's formidable IT industry.

Measured aggregate growth created nearly half a million new jobs in the years between 2003 and 2010 and some "hot" segments–high-flying renewable energy categories like wind energy and solar PV–doubled and tripled in size (albeit from small bases).

What is more, the data make clear that the clean economy is producing an array of positions useful to the nation's need to renew its economic base. Clean economy jobs are inordinately oriented toward manufacturing and exporting. Likewise, they offer an attractively balanced array of jobs and occupations, with substantially more opportunities and better pay for lower-skilled workers along with many positions in fast-growing "innovation" fields.

And yet, it must be said that the clean economy remains at present more an aspiration than a large center of present-day employment. A fraction of the size of the health industry, the U.S. clean economy remains small where it is fast-growing and relatively slow-growing on balance, as defined here. Moreover, the green economy encompasses–along with its newer, smaller, expanding private-sector firms–significant numbers of mature or public sector establishments that will not likely yield substantial growth in the future.

Overall, then, the clean economy in the U.S. and its regions should be deemed a diverse, multi-layered complex of both established and innovative pursuits, the older of which are important but sometimes mundane while the newer ones are frequently dynamic, emergent, and potentially transformative.

V. ADVANCING THE CLEAN ECONOMY

Fueled by innovation and private-sector entrepreneurship, numerous clean economy industries—particularly in the cleantech space—have emerged from the recent financial crisis and are progressing rapidly along relevant technology, cost, and employment measures.[1]

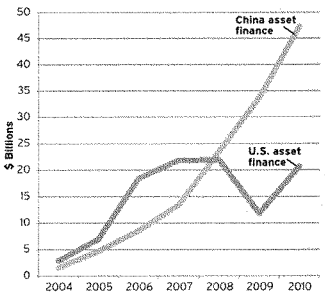
As a result, near double-digit annual growth in key segments and in key regions really does point to the possibility of the clean economy generating significant numbers of jobs in a variety of emerging global industries, whether it be cutting-edge renewable energy solutions and improved energy efficient building systems or integrated systems for water purification and environmental remediation.

And yet, notwithstanding the lack of comparable cross-national data in this report, serious questions surround the relative size and growth rate of the clean economy in the United States compared to in other countries.

Bloomberg data on the renewable energy sector depict a massive, growing shortfall between U.S. and Chinese asset financings—that of hard infrastructure like solar arrays, wind farms, or cellulosic ethanol refineries, which represent the most tangible form of industry scale-up.[2]

Likewise, while the nation still runs an overall trade surplus in environmental technologies on the "green" and "blue" side of the clean equation, U.S. firms are losing market share both at home and abroad to competitors from other nations.[3]

Figure 1. U.S. and China Clean Energy Asset Finance



Source: Bloomberg New Energy Finance

All of which raises the question of what governments and regional leaders should do–if anything–to catalyze faster, broader growth across the U.S. clean economy.

To be sure, the private-sector–influenced by local and world technology and market dynamics–will play the lead role in driving growth.

Much as they did in past waves of economic change, private initiative and private capital will do the lion's share of the work of turning ideas into business concepts and business plans into large-scale market breakthroughs.

In that sense, private-sector firms can and will step up with their own responses to environmental, security, and economic opportunity, whether by greening their ongoing business processes as Wal-Mart has because it reduces costs and appeals to customers, or moving as Google has done to build critical infrastructure with its plan to help construct a $5 billion underwater transmission line for future wind farms off the Atlantic coast, or collaborating to promote urban sustainability as a consortium of Charlotte businesses has with its Envision: Charlotte effort.[4] Private decisions, in this regard, will ultimately determine the size and impact of the clean economy in America and its regions.

However, the success of the private sector in delivering the clean economy will also depend on the existence of well-structured markets, a favorable investment climate, and a rich stock of cutting-edge technology–all matters shaped to a varying extent by government.

In this connection, the complication of virtually every segment of the clean economy–whether it be the water and wastewater industries or the energy segments–with a profusion of fundamental market flaws and institutional problems alone argues for a government role in unleashing greater market activity.

Likewise, the fact that significant policy uncertainties are likely depressing investment in the clean economy reinforces the need for engagement and reform. After all, neither entrepreneurs and companies, nor investors will commit large sums of capital to clean economy enterprises in the absence of a predictable policy outline.

And so it is clear that before truly vibrant private-sector growth and scale-up can occur in the clean economy super-sector there must be in place a clear, supportive, and stable policy outline that:

- Fosters demand and structures a vibrant domestic market
- Ensures the availability of adequate finance
- Promotes innovation

At the same time, it is essential that supportive conditions exist that:

- Keep the focus on regions

The *regional* build-out of the clean economy matters because local markets and regional industry clusters are where the clean economy actually takes place. Regions, after all, are the prime site of the day-to-day interactions by which real companies in real places develop new technologies, start new businesses, hire workers, and grow.

To that end, this report points to three critical areas of needed engagement–as well as the need to put regions at the center of future efforts–as Americans weigh how to advance clean economy growth at a time of global challenge.

In each case private sector-led growth needs to be co-promoted through complementary engagements by all levels of the nation's federal system.

MAKE A MARKET: CATALYZE VIBRANT DOMESTIC DEMAND

A first priority for unleashing clean economy growth must be to catalyze stronger market demand for clean economy goods and services.

Vibrant domestic market is critical because strong demand–or the expectation of strong demand–in a large and growing domestic market signals opportunity, attracts investment, and induces incremental innovation.[5] Over time, the presence of strong and steady domestic demand allows firms to scale up steadily and rapidly, lower their costs, and manufacture at home. Ultimately, strong and discerning domestic demand furnishes a route to global leadership.[6] And yet, the hard fact is that the United States does not yet boast strong demand for clean economy goods and services.

The problem: Policy gaps and uncertainties are depressing domestic demand

An array of policy gaps and uncertainties currently weaken the U.S. clean economy market. Some of these problems pervade almost the entire clean economy; others apply only to narrower portions of it, such as the clean energy segments encompassing energy efficiency and renewable energy or the water industry.[7] In any event, these market policy problems pose significant challenges to scaling up the clean economy.

To begin with, the lack of a coherent carbon pricing system places clean economy goods and services in the categories of energy and resource efficiency; greenhouse gas reduction, environmental management, and recycling; and renewable energy at a serious price disadvantage–which weakens demand for almost three-quarters of the clean economy. Absent such a price signal, clean economy goods and services remain relatively more expensive than they would if the harmful externalities of coal, oil, and other fossil fuel use–which range from greenhouse gas emissions and other air pollutants, to adverse health impacts such as lung disease and infant mortality to national security costs–were factored in.[8] As a result, the incentive for both households and businesses to buy clean goods and services and for the private sector to develop them is reduced.[9]

Spotty public-sector procurement efforts are another issue–missed opportunities for governments, as early adopters, to help create the market for clean economy goods and services. Given that the federal government purchases $500 billion in goods and services annually (states and local governments spend an additional $400 billion), occupies nearly 500,000 buildings, and operates more than 600,000 vehicles, the procurement of clean energy products and services, green buildings, and environmental remediation services represents an enormous opportunity for government supply chains to create and drive the market for clean economy growth.[10] Unfortunately, public sector procurement efforts remain limited and fragmented for a variety of reasons, including inadequate information on the environmental impacts and benefits of products and services, a lack of common standards for defining "green," real and perceived cost barriers to buying green products, and market and technical uncertainties about their benefits.[11]

Inadequate access to low-cost end-user financing for energy efficient (EE) retrofits and renewable energy (RE) installations stands as another hurdle to unleashing strong market growth. Low-carbon solutions–whether for installing water-efficient products and solar panels or undertaking deep whole-home retrofits–remain inherently capital intensive, with "first cost" investment barriers having proven difficult to overcome.[12] Therefore, it is unfortunate that while a variety of policy responses have been attempted, they have remained limited in scale, whether the mechanism be direct incentives such as grants and rebates; federal and state tax credits; or such finance instruments as revolving loan funds, utility on-bill financing, energy savings performance contracting, and property assessed clean energy (PACE).[13]

Creating a Market for Renewables: Germany's Feed-in Tariff

Germany is way ahead on renewable energy deployment and a key reason is the world's most aggressive market-making strategy.

A decade ago, Germany set out to create a transparent, stable, and predictable domestic market for renewables. Most notably, the ambitious Renewable Energy Sources Act, which came into force in 2000, established a feed-in tariff program that guaranteed that electricity produced from renewable energy sources (including hydropower, wind, solar PV, concentrated solar, biomass, geothermal, and landfill or sewage gas) would receive an above-market rate of return for 20 years. The tariff is designed to cover the cost of energy production plus a profit of 5 to 7 percent, with the rates adjusted every four years to reflect technological and price developments.

The tariff, in any event, has had several effects. For one thing, it has accelerated the uptake of renewable electricity in Germany to the point that the renewable sourcing has surged from 5 percent of the electricity market in the 1990s to 17 percent today. This vibrant domestic demand unleashed by the tariff has driven the growth of a large domestic market—and export base—for clean energy, with all of the attendant economic benefits.

Investment returns on renewable energy projects have been attractive in Germany, and ensured that numerous American companies like Google, First Solar, and Good Energies have invested there. In fact, clean energy investments in Germany reached $41.2 billion in 2010, a level that surpassed U.S. investment by a wide margin. As a result, moreover, significant job creation and export prowess have followed. In 2004, the renewable energy industry employed 160,000 people but by 2009 the number had jumped to more than 300,000. Germany is now also a global leader in the production of wind and hydroelectric turbines as well as solar panels.

As to the future of the program, it seems secure, notwithstanding opposition from big utilities as their losses of market share have increased. For one thing, initiatives to drive further renewables uptake will grow even more important in Germany with its recent decision to phase out nuclear energy development. For another, the feed-in tariff's success in increasing installed capacity, growing the manufacturing industry, attracting investment, and creating jobs has made it a popular program. In that sense, economic development success has bred political consensus.

Sources: Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety website and Energy Concept Paper (September 2010); Pew Charitable Trusts, "Who's Winning the Clean Energy Race?" (2011).

Even these programs may now be threatened given current state budget shortfalls and the looming ARRA funding "cliff," by which hundreds of millions of dollars in stimulus programs for clean energy projects will soon wind down.[14]

A series of structural and regulatory barriers in the electric power and water sectors also impede the adoption of clean technology solutions. Quasi-monopolistic and heavily regulated, electric utilities heavily intermediate consumer markets and demand, and do so with a mandated bias toward the least-cost, least-risk solutions. That means that these powerful incumbents have until recently been as slow to draw in renewable sourcing as they have been to help customers save electricity (both of which would elevate the demand for clean solutions). Similarly, the slow introduction of competition and deregulation into the drinking water and wastewater sector has led to a "safe and slow" mindset and a bias towards using conventional, familiar systems and technologies rather than innovative new ones.[15]

Finally, two policy problems that directly affect market-making in the renewable energy segment are worth noting. First, the lack of a national clean or renewable energy standard—a binding law that would require that utilities acquire a percentage of their electricity from renewable and other clean energy sources, perhaps including energy efficiency—has likely depressed demand for clean solutions. Even though the country has experimented with such standards at the state level with some success, it has not maximized their potential by developing a fully national market with the associated economies of scale that would help renewable energy technologies become cost-competitive.[16] The second problem afflicting this sector pertains to the efficient delivery of clean energy to metropolitan consumers which hinges on the existence of adequate transmission capacity to deliver the energy. Here too a welter of policy problems involving the planning, financing, siting, licensing, and building of transmission lines has contributed to delivery "bottlenecks," and rendered the current transmission line development system "close to dysfunctional."[17]

Overall, the combined effect of these policy gaps is a greatly weakened demand for clean economy goods and services and delays in the emergence of a vibrant, robust market in those products.

The strategy: Improve market access and demand

In view of these problems, a number of policy responses on the part of federal, state, and local leaders could help unleash more vibrant demand in the U.S. domestic market, essential for supporting innovation and exports.

In more expansive times, the federal government might take the lead in creating market making conditions through smart policy interventions with the states playing a collaborative and active role in reinforcing clean economy market creation. Ideally, Congress would **put a price on carbon** pollution to stimulate demand for clean products and raise revenue for needed RD&D investments. Or it might **pass a national clean energy standard (CES)** that creates a "floor" rather than a "ceiling" for state standards and insists on substantial renewable energy use to bring consistent, large-scale demand to clean electricity markets.[18] Or for that matter, Washington could **establish a series of clean economy "Races to the Top"** to spur states, utility commissions, and regions to develop and execute bold clean energy deployment plans or to accelerate the deployment and uptake of new and cleaner generation technologies.[19] (For a particularly bold national effort at market-making, see the sidebar on Germany's use of feed-in tariffs).

Unfortunately, however, such moves do not appear forthcoming in Washington. And yet, if "game-changing" major steps are not likely, progress actually seems possible on other important fronts in market-making.

At the federal level, **redoubled efforts to employ government procurement**—especially leveraging and reorienting the Department of Defense's vast purchasing power toward cleaner energy sources—as a source of stable demand appear possible via executive order and congressional action.[20] Similarly, **progress on appliance and equipment energy efficiency standards** ought to be possible in Congress and would save consumers money even as they ensured a strong domestic market for energy and water efficient products and services. And for that matter the Federal Energy Regulatory Commission (FERC) might well manage to institute regulatory adjustments to **ensure more rational cost recovery** on new transmission links needed to deliver renewable and other energy to urban load centers.[21]

States, on their part, can continue to play a critical role in inducing demand for clean economy goods and services. In this respect states have long led the nation in catalyzing market demand for clean goods and services. They have addressed this in multiple ways, ranging from their multi-state experiments with carbon pricing and their frequent RPS statutes to their energy efficient building codes and renewable fuel standards to their innumerable rebate and incentive programs, tax credits, and other programs aimed at reducing end-user costs.[22] Nonetheless, tremendous opportunities exist for states to accelerate their involvement in the market-making front.

To start with, states should build on their past leadership. Whether or not a national CES becomes a reality, states can increase the demand for clean electricity by **strengthening or adopting state-level clean energy standards.** These standards have worked well in increasing clean energy deployment and boosting local economies.[23] Therefore, states that have established CES or RPS rules should consider ratcheting up their targets for utilities while the 15 states that lack a target should consider implementing one.[24]

Similarly, states should **step up their own procurement efforts**, through which they can at once drive significant local demand for green and clean products and services even as they achieve cost savings across their facilities, operations, and fleets. One way to do this would be by establishing a comprehensive framework to underpin state-wide procurement policy, which would allow both for scaling up preexisting efforts and achieving economies of scale across programs while generating more demand for clean, green, and new sourcing.[25] And for that matter states should further drive demand by continuing to work on **reducing the initial costs of EE and RE investments** for residential, commercial, industrial, and institutional customers. This has been an important past role of the states, which should now innovate again as they design and implement a new generation of creative financing mechanisms that overcome first cost barriers, leverage private with public capital, and create financial products adapted to each distinct target sector.[26]

Finally, **electricity market reform** represents a significant market-making opportunity for states. Here too states can institute a range of reforms from developing regulatory structures to promote utility investment in clean energy programs (e.g., through program cost recovery, revenue stability, and performance-based incentives) to establishing uniform interconnection requirements for connecting distributed generation applications to the grid. More fundamentally, states should consider moving to the more transparent, competitive, and flexible model in which independent system operators (ISOs) or FERC-approved regional transmission organizations (RTOs) administer the planning of new infrastructure and the pricing of wholesale electricity. In addition to its role in lowering prices, the ISO / RTO model is more conducive to clean energy because the market shares generation and transmission over a larger geographic area and harbors fewer conflicts of interest in expanding capacity to accommodate new renewable generators or in allocating costs to market participants.[27]

Yet those are only federal and state engagements. Local governments and regional actors across the nation can also play a role in generating more robust demand for goods and services within the clean economy sector. This they can do in a multitude of ways. Local governments can accelerate renewable energy use by buying renewable energy for public buildings, expediting permitting for projects, reusing contaminated lands–such as brownfields, landfills, and Superfund sites–for renewable energy projects, and adopting financing tools such as PACE and power purchase agreements.[28] Local governments can also **adopt green building policies and ordinances** for new buildings while creating retrofit programs for existing buildings.[29] And for that matter, local governments can **improve the fuel efficiency of fleets** servicing their community which will drive the demand for clean vehicles and clean fuels from the bottom up. Local governments can also **step up to the challenges posed by climate change** by setting targets and drafting climate action plans to reduce greenhouse gas emissions.[30]

Figure 2. Many federal clean economy tax and related incentives expire in the next few years

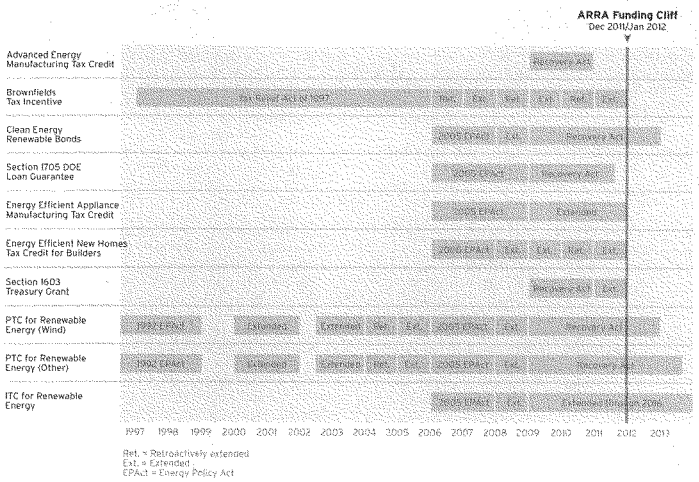
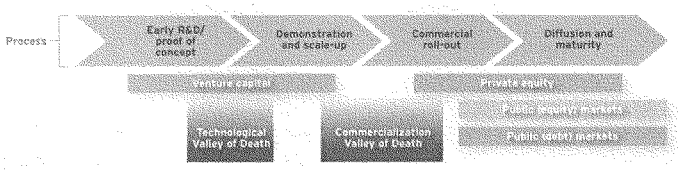


Figure 3. Multiple finance gaps complicate the scale-up of clean technologies



Source: Bloomberg New Energy Finance

ENSURE ADEQUATE FINANCE: ADDRESS THE COMMERCIALIZATION GAP

Market-making policies won't be enough, however. A second priority must be to address the serious finance problems that surround clean economy scale-up.

On this front, the availability of affordable capital of the right scale and with the right tolerance for risk is essential to all companies. Access to affordable finance matters inordinately in the clean economy because promising clean enterprises—whether in renewable energy or energy efficiency or water technology or air purification—often draw together intriguing but new technology, unusually heavy up-front capital requirements, and tricky regulatory or market settings.[31] Yet here again, the nation's current patchwork of responses to clean economy finance needs—especially in the energy field—remains sub-optimal and requires attention.

The problem: Responses to the deployment finance gap remain inadequate

On this front, the entire development chain through which clean economy goods and services are invented, proven, deployed, and scaled-up commercially is beset with finance challenges—challenges that have been thrown into relief by the massive recent clean energy investments of state-owned Chinese banks.[32] And yet, while significant attention over the years has focused on earlier-stage R&D and proof-of-concept challenges (the technology creation "Valley of Death"), larger finance problems located at the later-stage demonstration and deployment stage of the growth pathway now cry out the most for response—and yet remain unresolved.

The core issue is that a truly gargantuan "commercialization (or deployment) Valley of Death" now exists between the earlier R&D / technology proving stage and full-scale commercial roll-out, whether in energy or in other areas.[33]

At the earlier stage, government research dollars and VC capital are still managing to generate good ideas and provide entrepreneurial start-up companies with investments ranging from a few million to $20 million. At the very latest stages, traditional project finance and bank lending (ranging from perhaps $100 million to billions) is available for building out large, asset-based installations applying proven technology—whether it be a utility-scale solar array or a 50 million gallon cellulosic ethanol plant. However, in the intervening chasm—between the initial proof of concept that a VC can fund and the full-scale commercial roll-out typically financed by banks—few sources of capital exist for building critical initial pilot plants or scaling up advanced manufacturing facilities.

For which reason, a number of federal and to a lesser extent state initiatives have been set up to address the investment challenges of the commercialization Valley of Death—most notably the DOE's Loan Guarantee Program as well as a variety of federal and, in some cases, state tax credits. Unfortunately, though, multiple problems weaken the ability of these programs to draw private money into deployment and clean economy build-out.

The Loan Guarantee Program—which backs private loans to promising companies with new technologies—has been criticized as too slow-moving, too much engaged in "picking winners," as well as too conservative.[34] On the latter point, industry leaders, innovators, and analysts say that the program's requirements remain so stringent and prudent that they effectively replicate private-sector risk aversion—the problem the program is meant to address.[35]

As to the tax credits, these remain unstable—and are diminishing. Investors and deals require certainty, or at least predictability, about the terms and timeframe of the investment. However, U.S. deployment finance policy on the clean economy has been neither certain nor predictable (See Figure 2).[36] Cases in point are the federal Production Tax Credit (PTC) and the Investment Tax Credit (ITC) which have been allowed to lapse before being granted short-term extensions multiple times.[37] In fact, this unstable, on-again, off-again instability has affected multiple other important finance programs such as the EPA's Brownfields Tax Incentive.

Yet now things are poised to get worse. Most notably, the wind-down of ARRA's multiple provisions combined with other "sunsettings" of multiple tax code programs promises not just more "starts-and-stops" but a lot of "stops." A review of coming changes confirms, for example, that multiple clean economy-related tax provisions will expire by the end of 2011, including the Brownfields Tax Incentive, the Energy-Efficient Appliance Manufacturing Tax Credit, the Energy-Efficient New Homes Tax Credit for Home Builders, the Section 1603 Treasury Grant, and the Section 1705 Loan Guarantee Program. Other clean economy incentives such as the PTC for wind energy projects and the Clean Renewable Energy Bonds (CREB) program are set to expire by the end of 2012 (PTC for other qualifying projects end in December 2013).

In short, the whole rickety structure of the nation's main federal responses to the finance challenges faced by the clean economy faces a moment of reckoning—this at a time when the states' own engagements in clean economy finance also face resource shortfalls and rarely have the resources to address firms' later-stage need for large amounts of capital to support commercial-scale deployment.

The strategy: Address key finance gaps

Given these challenges, effective mechanisms need to be designed at all levels of the American system to draw in private capital and ensure the availability of adequate finance for clean economy scale-up.

To this end, the single most catalytic action that could be taken to advance the scale-up of new clean economy manufacturing and infrastructure could well be focused action by Congress to **create an emerging**

Ensuring Finance: China's Clean Economy Investment Strategy

China now leads the world in clean economy deployment. By the end of 2010 its 103 gigawatts of installed renewable energy generation capacity was more than double that of U.S. installations.

What explains China's success in rapid clean economy build out?

A huge part of the answer has to do with China's ability to channel vast sums of affordable capital into innovative large-scale deployment projects–something that the U.S. continues to struggle with. The numbers speak for themselves. In 2010, China put into place a staggering $54.4 billion in clean energy investments. Of this, asset financing–funding for hard assets like wind farms and solar arrays–accounted for more than $47 billion of the total. By contrast, U.S. private investment in clean energy totaled $34 billion, with just $21 billion or so in asset finance. Now the gap is widening further, with Chinese asset finance investment in Q1 2011 clocking in $10.9 billion as compared to just $2 billion in the United States.

What is China's secret in ensuring deployment finance? China has been inordinately successful in mobilizing large volumes of low-cost capital through its state-owned banks and other financial institutions. Clean energy projects have received preferential access to bank loans at interest rates far below what is available in other countries. Moreover, state-owned enterprises, especially the "Big Five" power companies, have been major investors across a broad range of energy conservation, pollution control, and renewable energy projects. For instance, China Guodian Corporation–one of the Big Five–recently announced a plan to invest $3 billion over the next five years in a variety of clean energy projects, including thermal, wind, natural gas, and biomass power stations in southwest China.

But that is only part of the story. Critical to China's success is its articulation of a comprehensive and long-term state clean energy build out policy that sends clear signals to investors. Through its 12th Five Year Plan, China has identified "new energy" as one among seven "strategic emerging industries" and will invest $760 billion over the next 10 years in this sector alone. A range of complementary policies will guide these investment decisions, including the Renewable Energy Law, national demand-side management regulations, and pilot carbon taxes, among others. China has swiftly made itself a clean energy power, in large part by ensuring the availability of copious, affordable capital at a time it has been short in the United States.

Sources: Bloomberg New Energy Finance; Pew Charitable Trusts, "Who's Winning the Clean Energy Race?" (2011); The Climate Group, "Delivering Low-Carbon Growth: A Guide to China's 12th Five Year Plan" (London: HSBC, 2011); written testimony by Julian Wong, Center for American Progress Action Fund, before the U.S.-China Economic and Security Review Commission (July 2010)

technology deployment finance entity to address the commercialization Valley of Death. (For China's aggressive parallel actions see sidebar).

To be sure, debates persist about the exact design of such a new entity. However, several sound models appear promising, including the proposed Clean Energy Deployment Administration (CEDA), which would provide loans, loan guarantees, and other credit enhancements to facilitate less expensive lending in the private sector; and the so-called Energy Independence Trust (EIT) concept developed by the Coalition for Green Capital, which would also expand access to low-cost financing to increase investment and lower the cost of deployment. Still other concepts being explored by the Coalition for Green Capital and the New England Clean Energy Council would channel stranded off-shore capital into U.S. clean economy scale-up through a qualified tax cut.[38] Either way the political moment–concerned about large scale deployment in China; frustrated with the DOE loan guarantee program–appears surprisingly favorable for what would actually be a cost-effective initiative with large returns. CEDA requires a $10 billion appropriation to catalyze a self-sustaining flow of private-sector finance for innovative deployment projects. The EIT, aimed at commercial-scale deployment of more mature technologies, would be authorized to borrow from the Treasury and repay the loans and so would require no appropriation. In both cases, any up-front costs could be paid off from a share of the revenue stream–making the programs virtually costless to taxpayers. For their part, the capital repatriation schemes would cost next to nothing. And yet, while the cost would be minimal, these mechansims' role in "de-risking" and helping finance large projects and so deploying game-changing technologies at scale could be no less catalytic than the Export-Import Bank's role in reducing the risk faced by exporters who contract with foreign buyers, or the Federal Crop Insurance Corporation's role in promoting investment in agriculture. Such institutions offer usable precedents for new clean economy finance mechanisms.

Also helpful on the finance front would be a push to **rationalize and reform the myriad tax provisions and incentives** that currently encourage capital investments in clean energy projects. In this respect, the expiration of multiple elements of the nation's mish-mash of federal deployment finance supports in fact represents an opportunity for reform. Such reform might well pair selective extensions of key production, investment, and manufacturing tax credits as well as the Treasury grant cash-back program with staged, technology-specific phase-outs, which would at once provide new industries support, predictability, and a nudge toward innovation and cost-reduction.[39] Alternatively, such a reform drive–which could be paired with a new look at reducing or eliminating subsidies to fossil fuel industries as well–might utilize competitive tendering processes like reverse auctions to contain subsidy expenditures and maximize the returns from given outlays.[40] In any event, the expiration of so many existing incentives at once is going to force a debate in the next two years and reform along the lines noted here might appeal at once to deficit hawks, members eager to provide tax benefits to the private sector, and others focused on unleashing investment and job-creation. Such a debate in Washington–paired with a serious focus on responding to the deployment finance gap–would be an auspicious development for the clean economy.

And yet, states and even regions themselves can play a huge role in accelerating the scale-up and deployment of new clean technologies and projects–as some are. For example, state development authorities–notwithstanding their limited financial and staffing resources–might consider supplementing private lending activity by **providing guarantees and participating loans** to in-state companies with promising new technologies. To be sure, the size of the relevant deals will surely fall below the $100 million to $500 million cited as the most intractable financial Valley of Death. However, when combined with private capital and other lending, state programs can still play a significant role in catalyzing the commercialization and deployment of clean technologies. Connecticut and California provide good examples of how this is being done.[41] The Connecticut Development Authority (CDA) provides up to $5 million in guarantees or supplemental financing for companies seeking to expand the production of promising new technologies. The CDA also leverages and

partially guarantees loans to clean economy companies by partnering with the U.S. DOE's Loan Guarantee Program through the Financial Institution Partnership Program (FIPP). Likewise, the California Energy Commission administers an Alternative and Renewable Fuel and Vehicle Technology Program, which authorizes loan guarantees and other financial measures out of an annual pool of approximately $100 million.

And states could go farther: In a related way, they could catalyze follow-in investment by setting up and **providing the initial funding for revolving loan funds** targeting clean economy projects using new or improved technologies.[42] Under this model, the state capital contribution could potentially be leveraged through the issuance of bonds to be repaid out of debt service. As repayments are made funds would be re-circulated into new loans. Such a model would be novel but not entirely different from California's Infrastructure and Economic Development Bank (I-Bank) or the revolving loan funds that many states use to support drinking and wastewater projects.

For their part, regions and localities can also help narrow the deployment gap, not so much through direct deployment finance as by reducing the costs and uncertainty of projects by expediting their physical build-out. In this respect, regional and local strategies to **manage zoning and permitting issues** or even **pre-approve sites** to facilitate new factory or project development would in their own way accelerate build-out by saving time and money.[43]

DRIVE INNOVATION: ACCELERATE TECHNOLOGY DEVELOPMENT

Recharging and renewing the U.S. innovation system is going to be critical too.[44]

Innovation (both radical and incremental) matters because too few clean technologies can yet compete with their incumbent competitors on an unsubsidized price basis–which remains the ultimate requirement if clean and green new technologies, processes, or services are to pervade the U.S. and world economy.[45]

To be sure, policies to catalyze market demand and facilitate financing will help scale up proven technologies and incremental innovations. However, a near consensus also insists on the imperative of complementing efforts to unleash demand with a strong push on technology development and deeper-going innovation.[46] Only through such a sustained technology push will society offset the serious market problems that prevent private firms from investing adequately to generate the next waves of products, processes, and business models, whether in cheap renewable energy, green materials, environmental remediation, or super-efficient water purification.

Yet, serious policy shortcomings continue to weaken the U.S. clean technology and processes innovation system and need to be addressed.

The problem: The nation's clean economy innovation system remains inadequate

Certainly, significant efforts have been made to improve the nation's innovation standing in recent years. However, these efforts remain inadequate in terms of both their scale and their format–and now appear in jeopardy.

In terms of their basic size, U.S. clean energy and environmental-sector technology development investments remain insufficient to ensure a steady stream of future incremental and radical technical advances.

On this front, a proliferation of market failures has long been recognized as arguing for a strong public investment role given that such problems discourage private firms from investing adequately in the technology development.[47] Yet even so, past Brookings reports (and many others) have documented the sub-optimal levels of recent federal innovation investments in the energy domain even as the current administration and Congress moved to improve them.[48] These recent steps forward have increased federal energy research, development, and demonstration (RD&D) investment–the sum of federal investments in energy system transformation–from just under $3.0 billion a year through much of the last decade to $4.7 billion in 2010 and to over $5.0 billion in the FY 2011 and 2012 budget requests.[49] Yet even these recently increased investment levels in energy innovation reflect a relatively low national investment intensity. To put current efforts in perspective, several analyses suggest a national expenditure of at least $15 billion to $25 billion annually would be necessary to bring the research intensity of the U.S. energy sector in line with that of other innovation-oriented sectors such as IT, biotech, or the semiconductor industry.[50] For more context, note that over the past two decades prior to the stimulus package U.S. energy R&D (which excludes demonstration) had declined steadily as a share of GDP to two-thirds of the OECD level.[51]

U.S. investments in water and environmental sciences also remain modest. For example, the EPA–far from the only federal agency to conduct environment-related R&D, but the one with the most applied and technology-focused portfolio–saw its R&D budget dwindle by a quarter to a low of $505 million in 2008 from its 2004 peak before it grew modestly to $538 million in 2010.[52] These investments amount to less than 0.01 percent of U.S. GDP–a figure just one-quarter the level registered by the rest of the OECD.[53]

And yet, even the sub-optimal investment levels detailed here now appear in jeopardy. Most notably, with the waning of federal stimulus investments and the rise of federal deficit anxiety, recent progress on improving the level of federal innovation investments of all kinds appears vulnerable. And neither will future reversals likely be offset by the increasingly active engagements on RD&D on the part of dozens of states–which, for their part, face tough choices on the use of their limited resources. Past state investments in energy R&D in particular have generated useful commercial innovations, but additional and sustained funding will be needed to create and build out innovative capacity in universities, industry, and the labor market–and it may not be available.[54]

But the problems weakening the nation's low-carbon and environmental innovation system go beyond the inadequate scale of current efforts. In addition, the format of innovation efforts also remains inadequate. Too much of the nation's past energy and environmental research has been based on an obsolete research paradigm, oriented heavily to either individual campus-based research projects or else to the highly "siloed," often insular and bureaucratic efforts of the DOE's energy laboratories.[55] On this front too, the Obama administration and Congress have in recent budget cycles responded–at least on the energy side–to calls for reforms. Most notably, the nation has begun to fund a trio of novel DOE start-up programs aimed at renovating the insular, stovepiped research approaches of the department. These include the Energy Frontier Research Centers (EFRCs), focused on multi-disciplinary scientific research on current barriers to technology progress; the Advanced Research Projects Administration-Energy (ARPA-E), focused on "high-risk, high-reward" projects in the translation stage; and the Energy Innovation Hubs, spanning the innovation and commercialization chain from invention to adoption.[56] Also laudable is the EPA's support of the Southeast Ohio-centered Water Technology Innovation Cluster (WTIC) program.[57]

Budgetary uncertainty now surrounds all of these experiments. After a stimulus infusion of $400 million for use in FY 2009 and 2010, for example, ARPA-E was allocated only $50 million in the initial FY 2011 budget proposal in H.R. 1 and ultimately received a modest $180 million in overall funding as a result of the recent budget deal struck by Congress.[58] Likewise, Congress has so far funded only three of the originally requested eight energy hubs, with funding for future years and more institutes appearing dicey.[59]

Advancing Energy Innovation and Technology: NYSERDA's Clean Energy Business Incubator Program

New York State is rapidly emerging as a leader in clean energy innovation, including through its statewide programs funding early-stage R&D, business incubators, and clean energy demonstration projects. Many of the state's efforts are being orchestrated by the New York State Energy Research and Development Agency (NYSERDA), a public benefit corporation created in 1975 by the New York State Legislature. NYSERDA's annual budget is approximately $620 million and its primary funding is derived from an assessment on the sale of electricity in New York State. NYSERDA has distinguished itself by undertaking a strong, tailored regional approach to promoting investment in emerging technologies and encouraging growth of the renewable and clean energy industry in New York state metro areas.

One way NYSERDA is fostering cleantech innovation is through promoting successful partnerships between early-stage cleantech companies and regional incubators that provide guidance, technical assistance and consultation to companies to help them develop and commercialize clean energy technologies. Since 2009, NYSERDA has invested nearly $9 million in six cleantech incubators through the Clean Energy Business Incubator program: Long Island High Technology Incubator, Inc. at Stony Brook University; Rochester Institute of Technology's Venture Creations; the University of Buffalo's Office of Science, Technology Transfer, and Economic Outreach; the Tech Garden at Syracuse; the NYC Accelerator for a Clean and Renewable Economy (ACRE); and the Incubator for Collaborating and Leveraging Energy and Nanotechnology (iCLEAN) at the University of Albany.

As of the end of 2010, with only 18 months of operation and $2.5 million in program expenditures, the Clean Energy Business Incubator program has already achieved significant results. The six incubators have nurtured the creation of several hundred net new jobs at client startup companies and the introduction of 26 new products to serve the clean energy market. They have assisted client companies in raising $16 million in private capital and attracting $11 million in federal funding, leveraging state expenditures by more than 10 to 1.

NYSERDA's efforts to help clean energy businesses develop and commercialize new energy technologies has been critical in helping New York create and retain the types of the companies that form the bedrock of a clean energy economy.

Source: NYSERDA's Clean Energy Business Incubators, available at www.nyserda.org/BusinessDevelopment/burpartners.asp; E-mail correspondence with Janet Joseph, NYSERDA.

Fostering Regional Innovation in Northeast Ohio: NorTech's Advanced Energy Roadmaps

Northeast Ohio—home to over several hundred clean economy companies—is well positioned to emerge as a leading center for innovation in technologies related to electric vehicles, energy storage, the smart grid, and waste-to-energy processes. Now, a regional economic development organization is moving to make sure that happens.

Serving as the focal point in Northeast Ohio for the advanced energy cluster, NorTech, a regional nonprofit economic development organization, is leading the development of a series of advanced energy technology and industry cluster roadmaps. Because industry roadmaps provide strategic guidance for economic development efforts to accelerate innovation and commercial activity, they can be a dynamic tool for setting priorities, allocating resources, aligning stakeholders, and focusing efforts. Along these lines, NorTech is using its extremely collaborative roadmapping model to identify the distinctive strengths of the region, characterize the relevant global markets' drivers and opportunities, assess the competitive landscape, articulate a shared vision for the region, and outline opportunities.

To begin with—and also to differentiate itself from other regions that are trying to build energy-related industries—NorTech has identified four sectors with compelling regional assets, global market opportunities, and potential to result in significant regional economic impact in the near term. Leveraging a $300,000 grant from the federal Economic Development Administration, NorTech has crafted roadmaps for the energy storage, smart grid, fuel cells, and waste-to-energy sectors that will ultimately enable the region to claim a large chunk of the burgeoning advanced energy market. As part of the roadmapping process, NorTech is also using "cluster sourcing" as a mechanism to foster innovation within the advanced energy cluster. Through this process, NorTech organizes and facilitates innovation working groups consisting of cluster members, researchers and other manufacturers in the value chain to attack specific challenges within the cluster and to develop new products in response to market opportunities.

In this way, the effort underway by NorTech and its Northeast Ohio partners epitomizes the sort of "bottom-up," data-informed organizing that fosters regional clusters, innovation, and job growth and advances the clean economy region by region.

Source: NorTech Energy Enterprise website; e-mail correspondence with Rebecca Bagley, NorTech.

The prospects are even bleaker for as-yet-unimplemented proposals such as one to create a number of regionally based clean economy innovation consortia to better connect the research community to market players in U.S. regions.[60]

The strategy: Keep working to improve the clean economy innovation system

To stave off retrenchment, then, and ideally to maintain forward progress on innovation system enhancement, federal, state, and regional actors will all need to combine doggedness and creativity.

Clearly no massive scale-up of energy and environmental innovation investment is likely in the near term. However, it ought to be possible for Congress to **embrace incremental growth of the energy and environmental RD&D budgets** even in the context of deficit reduction. And it ought to be possible for the body to affirm the value of its recent institutional experiments and **make incremental investments in the ramp up of the Energy Frontier Research Centers, ARPA-E, and the Energy Innovation Hubs.** Congress should therefore consider measured expansion of all of these programs and others, including a tripling of the ARPA-E budget, the creation of new hubs, the creation of a **water sciences innovation center**, and the establishment of a **regional clean economy consortium initiative.**[61] For resources there is no shortage of options: Revenue to support these investments could be located through the phasing out of counter-productive energy subsidies, the "off-budget" establishment of a small surcharge on electricity sales, the implementation of a small fee on imported oil, the dedication of revenues from a very low carbon tax, or even from the repatriation of "stranded" off-shore capital.[62]

But those are federal policy options. For their part, more states may choose to engage on innovation at a moment of rising need and limited resources. Many states, after all, are highly alert to the benefits of fostering the emergence of innovative clean industries and bring to the task important local knowledge and business connections. In this connection, state RD&D activity has been an important complement to federal leadership for years, and so many states have implemented a multitude of mostly modest-scaled efforts to invest in the RD&D process at all stages, whether by investing directly in research; supporting incubators in connection with local research universities; establishing seed funds to fill the funding gap between lab research and venture funding; or supporting demonstration projects.[63] (See sidebar on New York state's ambitious approach).

In view of that, it would be a good thing for the growth of the nation's clean economy if the states found ways to **maintain or expand their effort on RD&D** notwithstanding budgetary stress. And here there is a little-known resource to draw on—the state clean energy funds that exist in more than 20 states, supported by small public-benefit surcharges on electric utility bills.[64] These funds generate about $500 million per year in dedicated revenue, most of which goes to support individual project finance and deployment. Given the needs of the moment, channeling more of those flows into critical innovation (as well as economic development) activities represents an important option for maintaining and recharging states' clean economy innovation system. Yet, states will never have sufficient funds to invest comprehensively in traditional R&D and RD&D programs, making it critical that states **focus and prioritize their innovation investments**. To do this, states should complement stepped up investment effort with a sharper focus on the precise needs of promising innovation segments in the state economy. Central to this be a rigorous embrace of detailed sector, industry, and innovation system analysis such as a number of states and regions are now pursuing. (For background on Northeast Ohio's technology roadmapping exercise see sidebar). Only by employing fine-grained data and analysis to target interventions, drive design, and track performance will states maximize the impact of scarce innovation dollars.

* * *

Clarity on each of these fronts will drive growth because it will allow actors in the clean economy to locate customers, structure finance deals, and draw on leading-edge technology in a vibrant, predictable environment.[65]

But predictability of market-making, finance, and innovation will not be sufficient. Also important will be regional strategies, which more and more entrepreneurs, financiers, economic development leaders, and policymakers believe can play a critical role in bringing it all together. This priority runs along the lines that follow:

FOCUS ON REGIONS: BUILD THE CLEAN ECONOMY CLUSTER BY CLUSTER

Regions and the regional industry clusters they contain play a critical role in growth because they foster innovation, entrepreneurship, and job creation while promoting economic efficiency.[66]

Regions are the places where—within the federalist system—research is conducted, technologies are developed, ideas are shared, and new businesses started.[67] Regions, likewise, are the places where markets are tested, deals done, projects sited, and workers and suppliers located.

In fact, the importance of regions and clusters pervades this study, one of the most important findings of which remains the fact that the number of jobs in "clustered" clean economy establishments grew significantly faster than did the number in their more isolated counterparts. In this vein, industry clustering in the clean economy and elsewhere has increasingly been recognized as providing a useful and practical framework for shaping economic policy; catalyzing "bottom-up" strategy and execution; and coordinating fragmented policy offerings. And yet, notwithstanding a modest embrace of cluster concepts in recent economic discourse, much room exists for a more concerted focus on the importance of regions in clean economy development efforts.

The problem: Clean economy development efforts have placed too little emphasis on regional and industry cluster strategies

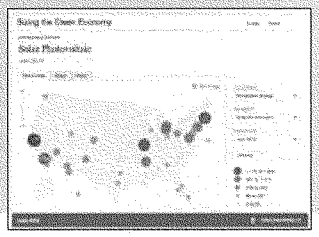
Too often place and the fact of industry clustering—the geographic concentration of interconnected firms and supporting or coordinating organizations—are left out of national clean economy discussions.[68]

To be sure, the reality of clustering in the clean economy has begun to inform federal policymaking in recent budget cycles, building on earlier inroads at the state level. Multiple federal agencies including the Economic Development Administration (EDA), the Small Business Administration, the Department of Agriculture, the National Science Foundation, and the Department of Labor now offer competitive grant programs for the modest support of regional cluster initiatives, including "green" ones.[69] In fact, several initiatives—such as the DOE's Energy Regional Innovation Cluster (Efficient Buildings) hub as well as this year's pending i6 Green Challenge to promote clean energy innovation and job growth—explicitly adopt cluster strategies into clean economy growth initiatives.[70] Likewise, a longer-standing orientation toward cluster strategies at the state level has seen the continued and accentuated application of the paradigm to clean economy initiatives in a number of states. States like Colorado, New York, and Oregon, have all applied a strong regional and cluster focus to their clean economy development initiatives.[71]

Visualizing the Clean Economy: The Metropolitan Policy Program's Interactive Mapping Tool

Far more data underlies this study of the clean economy than can be conveyed in the pages of this report. Yet, one of the core goals of this undertaking has been to provide detailed, actionable data to national, and especially regional, actors who have mostly lacked such information on the size, shape, and nature of the clean economy in U.S. regions. To that end, the Metropolitan Policy Program at Brookings has developed an interactive web-based mapping and downloads tool designed to provide in-depth access to the Brookings-Battelle Clean Economy Database that provides the basis for the analyses in this report.

Both map- and spreadsheet-oriented, the new tool allows users to visualize, or simply download data on, the geography of the clean economy at the state and metropolitan levels with an unprecedented richness of detail. Available on the site are jobs data—totals, shares, and growth—for the aggregate clean economy, five broad clean economy categories, and 39 narrower industry segments. Among the many possibilities users of the tool can disaggregate and study clean economy segments of interest, see where particular segment specializations exist, or find out where the clean economy is fastest growing (with the important caveat that the growth figures do not incorporate job losses from establishments that closed prior to 2010). Furthermore, the tool allows users to visualize the education profile of the clean economy's workforce as well as to probe wage characteristics, export orientations, and explore typical establishment ages. In all of this, the goal is to make the vast majority of the new information as widely available as possible while providing the greatest possible flexibility to users in its output and display. To explore the online application please visit the Brookings site at: www.brookings.edu/metro/clean_economy/map.aspx



Nonetheless, the leveraging of regional industrial and innovation dynamics for clean economy growth remains an under-exploited opportunity.

At the federal level, the nation's new array of regional development and green cluster offerings remains valuable but modest in scale—and frequently oversubscribed.[72] More importantly, the nation's chief energy-sector agency—the DOE—has until recently lacked a strong economic or regional development mission and still contends with a culture of insularity and aloofness from the marketplace that derives from the security mindset of its work in nuclear weapons development.[73]

At the state level, clean economy strategies do not always apply a well-focused regional emphasis—even when they adopt cluster concepts and terminology. Along these lines, state approaches to clean economy development—while well intentioned and frequently impressive—remain at times generic or ill-defined; insufficiently grounded in top-quality data analysis; or insufficiently "bottom-up."[74]

And then, while more and more regions are mounting their own increasingly strategic, locally specific initiatives to accelerate clean economy growth, not enough are.

On the positive side, regional self-assertion has emerged as a bright spot in the United States, with dozens of regionally-based intermediaries now moving to execute sophisticated growth strategies.

However, the fact remains that too few local clean economy growth campaigns are employing truly disciplined, data-rich, analytic approaches to ascertaining local specialization and accelerating home-grown growth. As at the state level, too few regions—given the limited cross-region data that has been available—have been able to assemble adequate information to really understand their clusters' market position and growth potential. Consequently, too many regional clean economy strategies focus on overly broad categories like "renewable energy" or "energy efficiency" rather than more distinctive sub-niches and developing strategy at that level.

Probably the most visible consequences of all of this inconsistent attention to cluster dynamics and locally-specific data, meanwhile, are workforce problems. On the one hand, concern has been mounting in some quarters about shortages of qualified workers, especially in the utility sector, to meet near- and long-term demand.[75] By contrast, though, more recent news and other reports—following on the investment of some $600 million of stimulus money in "green" training programs—have described situations in which the supply of trained clean economy workers has exceeded the regional market's need for them.[76] What links these seemingly opposite labor supply problems, it turns out, are widely recognized disjunctions between U.S. regions' workforce training systems and the local clean economy. Several studies note, after all, that clean economy worker training programs have neither been sufficiently data-driven nor informed by adequate partnerships between educational and training organizations, on the one hand, and employers, on the other.[77] These reports note that the multifariousness of the clean economy and its newness in some segments add to the usual challenges of securing sufficient communication and coordination among stakeholders to link industries' demands to the supply of workers.

Along these lines, it is plain that the inconsistent availability of objective, timely data about the size and growth of regional clean economy clusters has complicated the design of smart, realistic training and economic development systems at the regional level.

The strategy: Build the clean economy "bottom up," region by region

And so a broad strategy for all parties must be to place regional growth strategies specifically near the center of efforts to advance the clean economy.

At the federal level, the growing recognition in Congress of the value of regional strategies and local innovation clusters—as evidenced by the inclusion of a new "regional innovation program" in last year's America COMPETES reauthorization—encourages hopes that Congress will **support increased investment in new regional innovation and industry cluster programs.**[78] Competitive awards like the EDA's i6 Green Challenge for the establishment or expansion of regional proof of concept centers in various green technology fields has the power to further catalyze the "bottom up" clean economy development work that has broken out in numerous regions. Scaling such offerings up would accelerate growth. Funding options, while complicated in the current budgetary environment, do exist as noted in the financing discussion.

Carving a Niche in the Clean Economy: The Puget Sound's Regional Business Plan

One region that has taken bottom-up cluster development to a rigorous new level is the Puget Sound area, which has devised a hard-edged action plan to make itself a world center for a particular sub-area of the massive energy efficiency (EE) industry.

Working through a disciplined regional "business planning" process conducted in collaboration with the Metropolitan Policy Program at Brookings and RW Ventures LLC, Seattle's move has been to employ detailed data and analysis to reveal and begin to seize on its strong positioning for exporting building systems software and technology to the world.

The market opportunity is huge. McKinsey & Company estimates that $520 billion in investment is required to fully capitalize on the U.S. economy's energy savings potential through 2020. HSBC projects that the global building efficiency market will grow to $245 billion a year by then. Within this large market, the Puget Sound has targeted the building systems niche, which is projected to grow to $14 billion globally. In this niche, as it happens, the region already enjoys significant competitive advantage, ranging from a world-class array of large and small software and IT firms (arrayed around Microsoft); a significant EE consulting and services cluster anchored by McKinstry; a world-beating international business infrastructure; and the presence of progressive utilities and numerous military bases that are serving as early adopters for technology demonstration and deployment.

And so the region has devised a catalytic, bottom-up strategy to achieve its goal of world export preeminence: the creation of the Building Energy Efficiency Testing and Integration (BETI) Center and Demonstration Network. BETI will allow EE IT innovators in the region to test, integrate, and verify promising products and services before launching them to market, providing a potentially game-changing boost. BETI would be a self-financing entity whose real-world facilities firms and entrepreneurs would pay to access and whose validation would become industry standard, establishing the region as a global EE IT hub.

BETI's ambition and grounding in rigorous market analytics are exemplary in their own right. Even more significant, however, is what the region's complete business planning effort represents: a region coming together, taking the initiative to fundamentally understand its economy, and acting intentionally on the findings. While too many other states and regions fritter away money chasing the next hot cleantech fad, the Puget Sound is assiduously carving itself a niche in the next economy.

Source: "Innovation Meets Demonstration: A Prospectus for Catalyzing Growth in the Puget Sound's Energy Efficiency Cluster" (Brookings Institution, 2011); and Puget Sound Regional Council and Prosperity Partnership, "Business Plan for BETI" (2011), available at www.psrc.org/econdev/beti.

States, for their part, need to make regions and metropolitan areas central to clean economy growth strategies. State leaders need to understand and embrace the fact that the clean economy is significantly region- and metro-led.[79] What does that mean? By and large, it means that more states should empower regional clean economy cluster initiatives. States, to begin with, should work with the federal government and their regions–as many now are–to **improve the information base about local industry clusters**, with an emphasis on pulling together objective market analysis on their size, growth, market positioning, and challenges.[80] Too little is as yet known about these industries at the crucial regional level, and that has impeded good strategymaking.

Beyond improving the data, states can also play a critical role in advancing U.S. clean economy growth by making sure their clean economy activities **firmly support regionally crafted cluster strategies**. One way states can achieve this is through the provision of dedicated, modest-scaled resources–perhaps from state energy funds–to well-designed regional cluster initiatives.[81] For example, New York state has since 2009 invested nearly $9 million in six regionally-based and -oriented cleantech incubators through its Clean Energy Business Incubator program. Yet specifically titled formal "cluster" programs are only part of the picture. Equal or more value may in fact come from swinging other, more generally relevant, programs behind the regions' cluster strategies, whether it be related market-making procurement or utility initiatives; export promotion; particular finance interventions; various R&D, tech transfer, or other innovation initiatives; or workforce training policy. Such an alignment of multiple state activities with the needs of local clean economy clusters represents a low-profile but essential element of fostering growth

All of which leads to the critical role of regional actors themselves in accelerating the emergence of a dynamic clean economy in America. At this level, the needed development work will frequently be facilitative and focused especially on analysis and coordination: identifying promising local clusters, identifying the constraints they face, and facilitating joint regional action to address them.[82]

The first step for regions must be to **use data and analysis to understand the local clean economy in detail.** Currently, very few regions have access to the kind of rigorous, fine-grained information needed to make objective assessments about the nature, prospects, and needs of their local clean economies. Such data has simply not been widely available, given the difficulties of defining the clean economy and then of collecting the relevant information across diverse industries. And yet such statistical intelligence is absolutely essential to allow regions to define the terms; sort out fact from fiction; and focus regional strategy on truly viable, distinctive, and competitive networks of firms and establishments.

The data provided in this report, its appendices, and on an accompanying project website make a start. (See sidebar on visualizing the clean economy). Using this information, regions can obtain initial guidance on the relative size of their clean economy industry segments; the numbers of establishments and firms they contain; their growth; and their strength relative to those in other regions. In that way regions can begin to assemble what they in many cases do not have now: a basic empirical platform on which to base strategic clean economy development efforts.

With such a basic platform in place, regions should move to rigorously **identify clusters' binding constraints** and then move to **formulate strong, "bottom up" action** to address them. To the first point, a top priority of regional cluster participants and intermediaries should be to tease out the specific hurdles to the further growth of an area's most extensive, concentrated clusters. In this connection, rigorously identifying the most promising clusters on which to focus development efforts is part of the work but equal effort must drill down on isolating the specific impediments to future growth.

Are there local procurement sources that have not been exploited that could drive growth? Are there regulatory impediments that are precluding the siting of critical capital

Metro 'Greenprints' in Four Metropolitan Areas: The Climate Prosperity Network

Four very different metro regions—Silicon Valley, Denver, Portland, OR, and St. Louis—are pursuing assertive, bottom-up regional development strategies to move to a carbon-free future. These metros are partners in the Climate Prosperity Network, a national coalition of regions that share a common belief that they can simultaneously expand economic opportunities and reduce greenhouse gas emissions through practical strategies involving business, government, education, and other community partners.

Established in 2009, the network fosters the development of tailored "climate prosperity" strategies within the context of a shared commitment to the use of good economic information to identify regions' clean industry specializations; an effective collaborative process that focuses diverse partners on a few major strategic priorities; and visionary leadership—particularly from the business community.

Along these lines, while each region seeks to hone its unique comparative advantages, each is employing a common analytic framework that focuses on expanding market demand for clean economy products and services, as well as building the regional base of clean economy companies. The four metro areas are pursuing common market and business development strategies—including promoting use of local products, aggregating public procurement, branding and marketing regional specializations, expanding clean economy financing, growing regional supply chains, training a skilled workforce, and promoting commercialization, innovation, and entrepreneurship. They have also published strategies ("Greenprints") and established outcome metrics to track regional progress.

And yet, notwithstanding the common analytic framework, each region's greenprint capitalizes on its unique strengths and priorities. Silicon Valley is engaged in accelerating the "third revolution" clean technologies—with focus on renewable energy—by standardizing procurement and permitting for solar projects and promoting smart grid infrastructure. Metro Denver represents an integrated economic development strategy encompassing education and marketing of green products and services, building and documenting the cleantech value chain, and leveraging and commercializing the region's R&D assets. Metro Portland is using the greenprint process as a "call to action" to aggressively move itself along the clean economy pathway by expanding project finance, commercializing green technologies, cultivating the cleantech, sustainable forestry and agriculture clusters, and developing a skilled workforce. And St. Louis' first step in the process of developing its strategy has been to conduct a Green Economic Profile study that provides detailed metrics on the region's green economy.

Source: Climate Prosperity Network website, e-mail correspondence with Andre Pettigrew, Climate Prosperity Project Inc.

investments? Do businesses in the cluster lack access to financing owing, for example, to their distance from VC networks in Boston, New York, or Silicon Valley?

Such a drill-down will require fine-grained, often qualitative but still precise local information, including proprietary company data, detailed survey information, real-time market intelligence, and other forms of first-hand insight. For that reason such work to pinpoint local clusters' binding constraints will always be an inherently regional responsibility.

Why is such work so important? Such work is important because it represents the essential basis for "bottom up" regional action to address cluster needs and seize opportunities. Such regional assertiveness is critical, meanwhile, because it represents the best available source of locally grounded, cluster-specific information, priority-setting, and implementation.

And as it happens, numerous regions are engaged in this sort of disciplined, data-informed work to develop smart, place-specific development strategies.

Industry and economic development leaders in the Puget Sound area, for example, have collaborated with the Brookings Institution and RW Ventures LLC to craft a regional "business plan" reflecting that region's specific clean economy specialties, with a view to strengthening the global positioning of the region's EE technology cluster.[83] (See sidebar on the previous page). Similarly, the Climate Prosperity Project, a non-profit focused on the clean economy, has been working with four regions—San Jose, St. Louis, Denver, and Portland, OR—to develop locally tailored, empirically based clean economy "greenprints" to guide clean economy development in those metros.[84] (For more on Climate Prosperity and on regional networking in the Sacramento region see sidebar above). And for that matter, some 15 regions are now working together to forge common cause as they develop clean energy "innovation consortium" initiatives aimed at addressing innovation pipeline gaps and accelerating regional cluster growth in areas ranging from New England and Michigan to San Diego. In these ways, U.S. regions are moving assertively to define the needed interventions, implement them, and share their learning, whether through local initiative or through the targeting and tuning of various federal and state efforts.

Regional implementation steps can, should, and do vary widely. Backed by all kinds of entities, regional actions to advance the clean economy run the gamut of market-making, finance-oriented, innovation, and cluster development activities.[85] On market-making, for example, Climate Prosperity's efforts in Silicon Valley, Denver, Portland, OR, and St. Louis focus on expanding the demand for clean economy good and services by promoting use of local products, aggregating public procurement, and branding and marketing regional specializations.[86] To address finance issues in its region, the Clean Tech Center at the Syracuse-based Tech Garden offers technical and financial assistance—by facilitating access to angel investments and venture capital—to entrepreneurs and early stage companies to foster clean technology business development.[87] In Wisconsin, meanwhile, the Milwaukee Water Council is working to catalyze water-tech innovation in a cluster that includes more than 100 scientists and 130 water technology companies.[88] And for that matter, CleanTECH San Diego in California, a non-profit membership organization, has developed a comprehensive one-stop-shop to advance the region's clean economy by helping companies coordinate with established research facilities to identify both synergies and gaps and network through an online registry of the region's growing cluster of clean technology companies.[89]

Among all these activities two more stand out. Given the prominence regional leaders retain on land use, regional and local officials have special power to **manage the zoning and permitting issues** that can determine how quickly and where key clean economy infrastructure or installations are sited within the demographic and workforce contexts of their communities.

Likewise, regional leaders' sensitivity to local population and business dynamics argues that they should lead efforts to **improve regional clean economy workforce development.** And here, too, regional cluster knowledge and the collection of detailed cluster data allow for improved outcomes. Too often in U.S. regions workforce training for

Advancing the Clean Economy in California's Capital Region: Sacramento's Clean Technology Story

Regional networking—and using it to devise a regional investment strategy—has brought new focus to the Sacramento region's efforts to become a hub for clean energy technology. Leading the way has been the Green Capital Alliance (GCA). The GCA unites public and private partners, including the regional economic development organizations, workforce development organizations, non-profits, the regional council of governments, and academic institutions, in common cause to make clean technology a defining feature of Sacramento region's economy.

GCA is working to develop an investment strategy for the clean energy sector that will become the central plan guiding the clean energy-related work of its partners. As part of that, GCA holds Clean Energy Technology (CET) Business Roundtables to assess opportunities in the cleantech industry, stay in tune with market realities, and make sure regional education and workforce training programs meet the industry's needs. The roundtables are also helping shape the high-level strategies emerging from Mayor Kevin Johnson's "Greenwise Sacramento" initiative, which aims to transform Sacramento into the greenest region in the country.

Sacramento has enjoyed considerable success of late in securing state and federal investment, which leaders credit in part to its now renowned collaborative approach and ability to articulate a clear regional vision. The region has also witnessed significant private investment, with the Bank of America playing a pivotal role in GCA's CET Business Roundtables by providing financial insight into the region's clean technology cluster expansion. The Sacramento Area Regional Technology Alliance (SARTA) has been chosen as one of the state's six Innovation Hubs (iHubs) with an emphasis on clean technologies. Meanwhile, University of California, Davis—a GCA partner and home to the nation's first university-based Energy Efficiency Center—supports the region's commercialization of clean energy through major research initiatives in lighting and cooling efficiency, clean transportation, and renewable energy.

The region's efforts are already producing significant results. The clean economy in the Sacramento-Arden-Arcade-Roseville metro area grew 59 percent from 2003 to 2010. Although much of this growth was driven by large state agencies, the presence of the electric vehicle technologies, solar thermal, and solar photovoltaic segments increased markedly and signals a building out of Sacramento's cleantech economy that is gaining momentum.

Sources: Green Capital Alliance website; Sacramento Area Commerce & Trade Organization website.

so-called "green jobs" (as well as other occupations) has proceeded on its own track, aspirational about what job placements training might yield and divorced from the latest market trends and real industry demand in local places.[90] The result has been disturbing shortages and surpluses of particular types of workers. However, the availability of improved data and more assertive cluster initiatives points to a better way—and one of the most important future roles of metropolitan and rural regions in advancing the clean economy. Along these lines, the use of fine-grained segment data and better communication in the design and management of worker training efforts should make possible a much more accurate tuning of training efforts to true private sector needs—and better connection of workers to opportunities. Proving that it can be done, some community colleges and other regional intermediary organizations have successfully linked training to cluster-specific industry needs with considerable success. For instance, the Los Angeles Trade-Technical College grounds all of its work on "green jobs" with careful research and industry engagement to inventory "real" employment opportunities and future demand.[91] Likewise, the Workforce Development Council of Seattle/King County (WDC) has gone to great lengths to aligning its workforce development efforts with private sector needs. First, the WDC convened an industry panel to explore market dynamics and employer needs in the area of green design and construction. Then the WDC partnered with the City of Seattle and other organizations to launch a new industry-led project to understand and meet employer needs in the residential and commercial building energy efficiency sectors.[92]

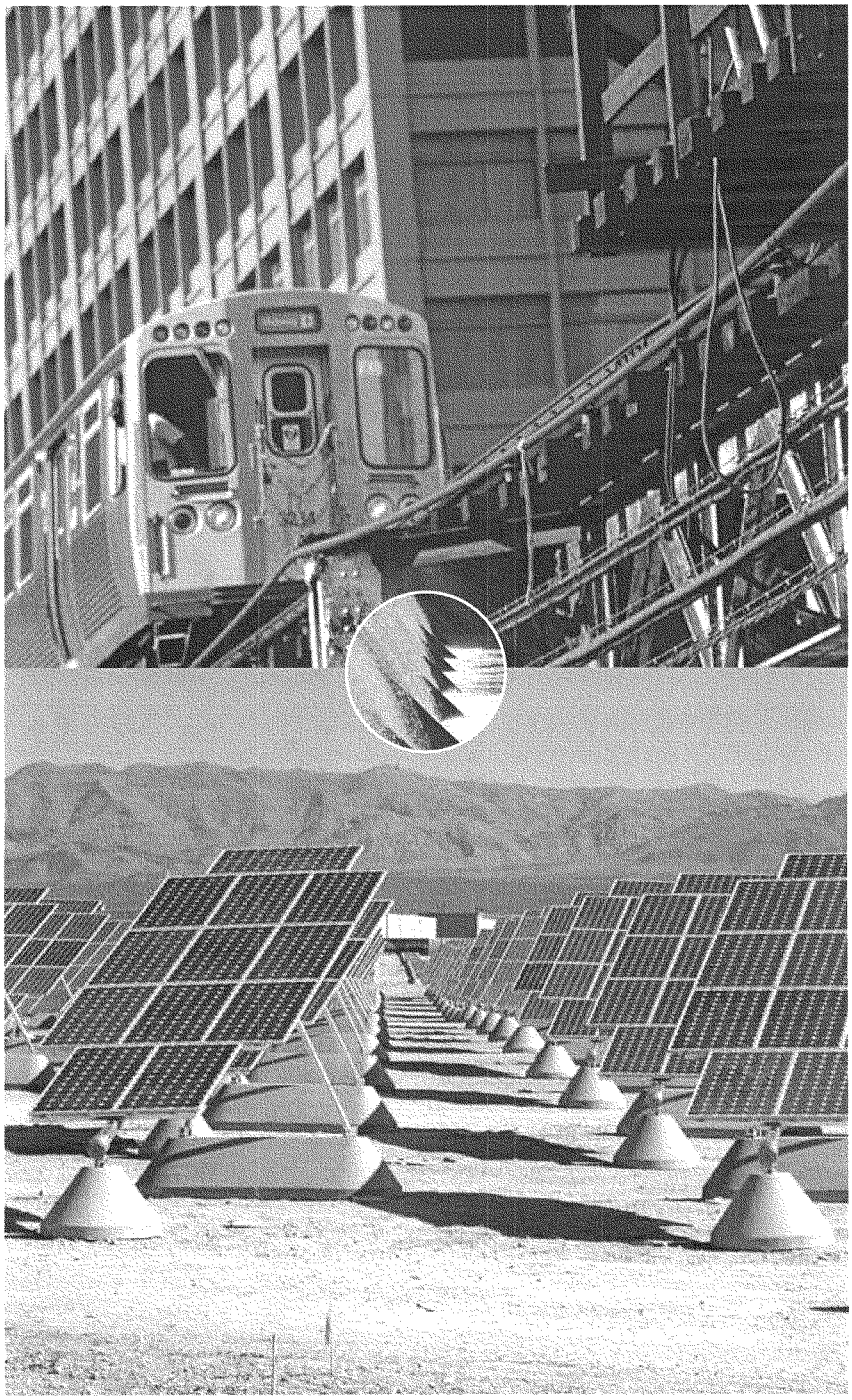
* * *

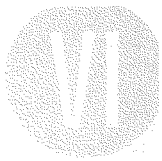
The takeaway is clear: While private enterprise ultimately will deliver a robust clean economy, federal, state, and local governments all have roles to play in co-producing a clear, supportive, and stable growth environment for it.

In that role, government must work to structure a vibrant domestic market, ensure the availability of finance, and keep the innovation pipeline charged. Throughout, regions and clean economy industry clusters must move to the center of development efforts.

Ultimately, by pursuing this course, the nation can and will build the domestic clean economy, firm by firm, and region by region.

While private enterprise ultimately will deliver a robust clean economy, **federal, state, and local governments all have roles to play** in co-producing a clear, supportive, and stable growth environment for it.





CONCLUSION

The measurements and trends reviewed here offer an encouraging but also challenging assessment of the ongoing development of the clean economy in the United States and its regions.

In many respects, the analysis warrants optimism.

As the nation continues to search for new sources of high-quality growth, the present findings depict a sizable and diverse array of industry segments–in key private-sector areas–expanding rapidly at a time of sluggish national growth.

Already the aggregate clean economy employs more people than the fossil fuels and biotech industries. More importantly, a dozen or so "hot" segments–mostly dynamic renewable energy categories like wind energy, solar photovoltaic, and smart grid–doubled and tripled in size in the last decade, answering the hype that has surrounded them despite extremely difficult recent market and finance conditions.

What is more, the analysis suggests that the clean economy is producing jobs relevant to the nation's need to renew its economic base. Clean economy jobs are inordinately oriented toward manufacturing and exporting. Likewise, the segments of the clean economy encompass a balanced array of jobs and occupations, with substantially more opportunities and better pay for lower-skilled workers along with other positions in higher-end "innovation" fields. Having more clean economy jobs as the sector's younger, more innovative segments advance in technology, deployment, and market-penetration would be good for the nation.

Yet, the information here also underscores several challenges.

For one thing, the data counsel against excessive hopes for large-scale, near-term job-creation from the sector. After all, the U.S. clean economy remains small where it is fast-growing and relatively slow-growing on balance, as defined here. That means that while key clean economy growth segments appear of critical importance to America's future, their status as major employers remains a few years off.

Beyond that, what is more concerning about the future outlook is that the growth of the clean economy has almost certainly been depressed in recent years by significant policy problems and uncertainties.

America, its industries, and its regions are in many places making solid progress on clean economy development, especially at the early-stages of the technology commercialization pathway, where new ideas, business plans, and firms come into being. However, much evidence suggests that the scale-up of these ideas has not been maximized, due in part to policies that have left domestic demand weaker than it might be, financing harder to obtain, and the innovation pipeline unsecured for the future, even as too little attention is paid to the regional underpinnings of growth.

In that sense, what is most challenging here is the fundamental question raised by the dynamic growth but modest size of the most vibrant and promising segments of the clean economy.

That question is: Will the nation marshal the will to make the most of those industries?

In the end, it is a question raised frequently by these pages. ◎

APPENDIX

Appendix A. The U.S. Clean Economy by Category and Segment

Category/Segment	Jobs, 2003	Jobs, 2010	Annual average change in jobs, 2003-2010 (%)	Clean economy share of all U.S. jobs, 2010 (%)	Median age of establishment (in years) 2010	Exports per job, 2009	Share of jobs held by workers with a high school diploma or less, 2010 (%)	Share of jobs jobs that are green collar, 2010 (%)	Average annual wage, 2009	Share of traded sector establishments that are clustered, 2010 (%)
Agricultural and Natural Resources Conservation	**374,120**	**505,993**	**4.4**	**0.4**	**15**	**$13,239**	**39.4**	**58.5**	**$42,721**	**10.5**
Conservation	193,836	314,983	7.2	0.2	14	$466	27.1	50.6	$47,121	8.0
Organic Food and Farming	114,931	129,956	1.8	0.1	23	$29,677	59.5	65.1	$35,946	17.9
Sustainable Forestry Products	65,353	61,054	-1.0	0.0	18	$44,146	60.1	83.7	$34,442	6.2
Education and Compliance	**95,064**	**142,156**	**5.9**	**0.1**	**15**	**$233**	**29.0**	**59.1**	**$45,865**	**18.6**
Regulation and Compliance	95,064	141,890	5.9	0.1	15	$232	29.0	59.1	$45,879	19.8
Training	0	266	N/A	0.0	21	$768	40.2	50.3	$38,345	7.0
Energy and Resource Efficiency	**675,391**	**830,146**	**3.0**	**0.6**	**16**	**$21,187**	**49.3**	**75.0**	**$38,073**	**11.3**
Appliances	45,671	36,608	-3.1	0.0	21	$56,838	54.0	77.8	$37,980	8.3
Battery Technologies	14,605	16,129	1.4	0.0	8	$81,867	44.9	64.0	$43,011	13.1
Electric Vehicle Technologies	10,264	15,711	6.3	0.0	8.5	$124,825	53.7	78.1	$38,324	18.2
Energy-saving Building Materials	135,911	161,896	2.5	0.1	17	$20,788	58.7	81.6	$36,786	3.4
Energy-saving Consumer Products	23,615	19,210	-2.9	0.0	17	$56,040	49.2	71.4	$40,725	16.9
Fuel Cells	3,542	7,041	10.3	0.0	10	$74,746	33.9	46.1	$50,287	29.6
Green Architecture and Construction Services	36,512	56,190	6.4	0.0	21	$4,908	26.0	32.9	$56,487	32.7
HVAC and Building Control Systems	58,654	73,600	3.3	0.1	17	$46,776	45.0	65.2	$42,806	8.3
Lighting	16,269	14,298	-1.8	0.0	18	$47,922	49.6	71.4	$39,469	24.2
Professional Energy Services	31,161	49,863	6.9	0.0	9	$30,207	20.5	26.2	$56,063	21.8
Public Mass Transit	267,946	350,547	3.9	0.3	21	$53	54.4	90.3	$30,947	11.8
Smart Grid	8,986	15,987	8.6	0.0	10.5	$35,108	33.4	48.2	$48,758	12.8
Water Efficient Products	22,255	13,066	-7.3	0.0	18	$57,487	50.2	72.9	$39,479	17.2

Appendix A. The U.S. Clean Economy by Category and Segment (continued)

Category/Segment	Jobs, 2003	Jobs, 2010	Annual average change in jobs, 2003–2010 (%)	Clean economy share of all U.S. jobs, 2010 (%)	Median age of establishment (in years) 2010	Exports per job, 2009	Share of jobs held by workers with a high school diploma or less, 2010 (%)	Share of jobs jobs that are green collar, 2010 (%)	Average annual wage, 2009	Share of traded sector establishments that are clustered, 2010 (%)
Greenhouse Gas Reduction, Environmental Management, and Recycling	**854,247**	**1,058,886**	**3.1**	**0.8**	**16**	**$19,432**	**45.5**	**69.6**	**$40,644**	**10.3**
Air and Water Purification Technologies	18,072	24,930	4.7	0.0	17	$63,028	47.6	67.9	$39,136	19.6
Carbon Storage and Management	163	391	13.3	0.0	8	$26,678	38.4	55.3	$47,462	14.3
Green Building Materials	69,496	76,577	1.4	0.1	20.5	$32,714	61.1	85.3	$34,191	13.4
Green Chemical Products	28,795	22,622	-3.4	0.0	18	$178,861	48.9	72.8	$39,061	8.1
Green Consumer Products	77,032	77,264	0.0	0.1	18	$48,205	55.4	78.9	$36,069	19.1
Nuclear Energy	66,936	74,749	1.6	0.1	16	$10,733	36.7	66.0	$45,843	12.6
Pollution Reduction	11,024	9,986	-1.4	0.0	18	$27,431	31.0	41.4	$48,133	16.0
Professional Environmental Services	89,253	141,046	6.8	0.1	14	$16,104	20.2	26.7	$55,235	16.7
Recycled-Content Products	56,475	59,712	0.8	0.0	18	$62,637	58.1	85.0	$35,316	11.4
Recycling and Reuse	89,584	129,252	5.4	0.1	17	$1,805	51.3	75.4	$36,463	10.0
Remediation	40,702	56,241	4.7	0.0	14	$1,316	52.9	78.7	$40,101	9.2
Waste Management and Treatment	306,715	386,116	3.3	0.3	16	$3,428	46.6	76.4	$38,795	8.3
Renewable Energy	**111,386**	**138,364**	**3.1**	**0.1**	**6**	**$64,884**	**43.3**	**69.4**	**$43,070**	**14.6**
Biofuels/Biomass	11,384	20,680	8.9	0.0	6	$189,088	45.3	67.1	$41,010	7.9
Geothermal	1,722	2,720	6.7	0.0	12	$8,131	46.8	73.6	$42,772	17.1
Hydropower	71,625	55,467	-3.6	0.0	20	$300	37.5	68.8	$45,226	10.0
Renewable Energy Services	1,294	1,981	6.3	0.0	8	$17,650	40.5	63.6	$46,884	19.6
Solar Photovoltaic	11,866	24,152	10.7	0.0	5	$80,464	45.0	66.7	$43,858	29.4
Solar Thermal	1,647	5,379	18.4	0.0	9	$36,801	53.3	70.8	$35,652	19.6
Waste-to-Energy	2,566	3,320	3.7	0.0	20	$513	49.4	76.6	$40,466	25.9
Wave/Ocean Power	98	371	20.9	0.0	4.5	$11,291	19.6	23.0	$59,368	20.0
Wind	9,184	24,294	14.9	0.0	6	$117,164	49.8	75.1	$40,588	12.0
Aggregate Clean Economy	**2,110,208**	**2,675,545**	**3.4**	**2.0**	**15**	**$20,129**	**44.6**	**68.7**	**$43,773**	**10.9**

Source: Brookings-Battelle Clean Economy Database; exports: Brookings analysis of U.S. International Trade Commission, Bureau of Economic Analysis, Internal Revenue Service, Institute of International Education, and Moody's Analytics data; educational attainment: U.S. Bureau of Labor Statistics Employment Projections Program; green collar jobs: U.S. Bureau of Labor Statistics Occupational Employment Statistics and Employment Projections Program; wages: U.S. Bureau of Labor Statistics Occupational Employment Statistics; clusters: Brookings analysis (see external methods appendix for details).

Appendix B. The Aggregate Clean Economy by State

State	Jobs, 2003	Jobs, 2010	Annual average change in jobs, 2003-2010 (%)	Clean economy share of all state jobs, 2010 (%)	Median age of establishment (in years) 2010	Exports per job, 2009	Share of jobs held by workers with a high school diploma or less, 2010 (%)	Share of jobs jobs that are green collar, 2010 (%)	Average annual wage, 2009	Share of traded sector establishments that are clustered, 2010 (%)
Alabama	32,592	38,182	2.3	1.9	14	$23,684	47.7	72.8	$36,260	1.6
Alaska	8,439	16,682	10.2	4.7	12	$2,294	33.2	56.5	$48,778	1.3
Arizona	29,896	37,257	3.2	1.5	14	$13,504	43.6	68.2	$38,831	14.1
Arkansas	27,920	32,450	2.2	2.6	15	$42,450	49.9	73.7	$32,116	6.6
California	239,064	318,156	4.2	2.1	16	$16,314	43.1	64.2	$46,400	41.0
Colorado	34,787	51,036	5.6	2.2	14	$23,165	38.2	59.7	$45,973	5.5
Connecticut	22,541	29,751	4.0	1.8	16	$11,793	42.5	67.6	$45,802	8.7
Delaware	4,873	6,917	5.1	1.6	15	$13,830	38.7	57.6	$46,607	5.5
District of Columbia	20,302	22,462	1.5	3.1	14	$2,454	38.4	65.4	$52,608	37.5
Florida	74,669	102,967	4.7	1.4	13	$9,386	41.5	65.6	$38,085	2.1
Georgia	64,709	83,707	3.7	2.1	13	$20,216	48.1	72.3	$36,764	10.6
Hawaii	7,144	11,113	6.5	1.7	13	$4,913	42.0	66.1	$42,235	4.7
Idaho	12,992	17,543	4.4	2.7	15	$10,514	42.3	65.2	$36,359	0.7
Illinois	86,084	106,375	3.1	1.8	17	$25,917	45.5	70.7	$41,357	22.4
Indiana	48,352	53,684	1.5	1.9	16	$29,777	48.2	73.0	$37,162	5.5
Iowa	24,574	30,835	3.3	2.0	17	$44,942	51.4	77.0	$35,237	0.8
Kansas	22,179	27,199	3.0	1.9	16	$26,853	43.2	65.4	$38,733	2.0
Kentucky	32,011	36,963	2.1	1.9	16	$39,948	48.1	72.8	$35,585	3.5
Louisiana	28,468	28,673	0.1	1.5	15	$19,443	45.2	70.3	$36,493	2.3
Maine	9,298	12,212	4.0	2.0	18	$14,158	44.1	69.3	$36,460	0.8
Maryland	34,837	43,207	3.1	1.7	15	$9,143	41.3	65.2	$44,790	0.3
Massachusetts	50,598	63,523	3.3	2.0	17	$16,166	42.4	65.4	$47,815	23.1
Michigan	78,537	76,941	-0.3	1.9	17	$26,589	48.6	73.3	$40,558	5.3
Minnesota	41,752	58,232	4.9	2.1	16	$21,868	46.7	70.7	$41,240	10.3
Mississippi	17,730	20,905	2.4	1.8	13	$25,010	50.2	75.1	$31,053	3.5
Missouri	36,496	43,736	2.6	1.6	15	$27,868	44.7	69.4	$38,401	5.4
Montana	11,850	14,235	2.7	3.1	15	$8,970	33.3	54.0	$37,860	0.0
Nebraska	10,286	15,311	5.8	1.5	18	$20,940	45.1	67.6	$36,323	5.8
Nevada	11,167	16,578	5.8	1.5	13	$7,872	39.4	60.3	$44,545	10.9
New Hampshire	8,971	12,886	5.3	2.0	16.5	$14,449	42.8	67.6	$40,773	0.8
New Jersey	68,127	94,241	4.7	2.4	18	$13,639	45.8	72.6	$43,809	4.3
New Mexico	11,818	17,725	6.0	2.1	14	$10,380	37.5	61.6	$39,327	4.2
New York	124,848	185,038	5.8	2.1	18	$13,149	44.6	71.6	$44,056	10.2

Appendix B. The Aggregate Clean Economy by State (continued)

State	Jobs, 2003	Jobs, 2010	Annual average change in jobs, 2003-2010 (%)	Clean economy share of all state jobs, 2010 (%)	Median age of establishment (in years) 2010	Exports per job, 2009	Share of jobs held by workers with a high school diploma or less, 2010 (%)	Share of jobs jobs that are green collar, 2010 (%)	Average annual wage, 2009	Share of traded sector establishments that are clustered, 2010 (%)
North Carolina	52,780	78,881	5.9	1.9	14	$25,774	45.7	70.3	$37,348	9.1
North Dakota	4,537	7,146	6.7	1.7	14	$61,299	47.0	72.4	$35,547	2.7
Ohio	88,513	105,306	2.5	2.0	17	$25,067	45.5	69.9	$39,275	5.1
Oklahoma	13,903	19,297	4.8	1.2	16	$10,491	43.6	71.0	$33,673	0.0
Oregon	50,482	58,735	2.2	3.4	18	$13,484	46.0	68.2	$40,072	6.0
Pennsylvania	99,334	118,686	2.6	2.1	17	$15,709	46.0	71.7	$39,266	10.4
Rhode Island	9,017	9,563	0.8	2.0	14.5	$32,274	45.0	68.9	$41,442	0.0
South Carolina	46,659	50,424	1.1	2.7	15	$38,172	47.0	71.5	$36,373	1.3
South Dakota	5,459	6,659	2.9	1.5	15	$42,092	42.7	69.2	$33,880	0.0
Tennessee	58,456	76,031	3.8	2.8	13	$50,939	42.8	65.5	$37,347	3.4
Texas	115,194	144,081	3.2	1.3	13	$16,703	45.0	68.7	$37,926	28.2
Utah	14,312	18,261	3.5	1.5	14	$10,699	45.2	70.3	$36,637	3.6
Vermont	8,295	9,425	1.8	3.0	15	$22,377	48.2	71.5	$37,681	0.0
Virginia	48,423	66,772	4.7	1.7	14	$11,034	40.6	65.8	$43,400	11.4
Washington	69,106	83,676	2.8	2.8	16	$14,363	44.0	64.9	$46,457	26.0
West Virginia	10,587	12,659	2.6	1.6	17	$12,835	44.0	70.5	$33,805	0.0
Wisconsin	73,093	76,858	0.7	2.7	18	$27,674	50.2	75.3	$37,931	7.5
Wyoming	4,147	6,363	6.3	2.1	14	$5,612	33.3	57.1	$41,503	0.0
United States	**2,110,208**	**2,675,545**	**3.4**	**2.0**	**15**	**$20,129**	**44.6**	**68.7**	**$43,773**	**14.2**

Source: Brookings-Battelle Clean Economy Database; exports: Brookings analysis of U.S. International Trade Commission, Bureau of Economic Analysis, Internal Revenue Service, Institute of International Education, and Moody's Analytics data; educational attainment: U.S. Bureau of Labor Statistics Employment Projections Program; green collar jobs: U.S. Bureau of Labor Statistics Occupational Employment Statistics and Employment Projections Program; wages: U.S. Bureau of Labor Statistics Occupational Employment Statistics; clusters: Brookings analysis (see methods external appendix for details).

**State and metro clustering figures exclude non-exporting segments, defined as those with less than $4000 in exports per job. This is why the clustering figure for the United States seen here does not match the figure in Appendix A.*

Appendix C. The Aggregate Clean Economy in the 100 Largest Metropolitan Areas

Metropolitan Area	Jobs, 2003	Jobs, 2010	Annual average change in jobs, 2003-2010 (%)	Clean economy share of all metro jobs, 2010 (%)	Median age of establishment (in years) 2010	Exports per job, 2009	Share of jobs held by workers with a high school diploma or less, 2010 (%)	Share of jobs that are green collar, 2010 (%)	Average annual wage, 2009	Share of traded sector establishments that are clustered, 2010 (%)
Akron, OH	4,355	5,445	3.2	1.7	16	$11,788	46.4	72.9	$38,120	0.0
Albany-Schenectady-Troy, NY	15,557	28,087	8.8	6.3	15.5	$44,114	34.3	56.6	$48,087	9.1
Albuquerque, NM	5,851	9,912	7.8	2.6	16	$14,180	38.1	61.8	$40,145	6.9
Allentown-Bethlehem-Easton, PA-NJ	5,509	6,770	3.0	2.0	18	$11,992	47.0	74.4	$37,766	0.0
Atlanta-Sandy Springs-Marietta, GA	28,922	43,060	5.9	1.9	12	$15,089	43.2	66.3	$40,602	8.6
Augusta-Richmond County, GA-SC	9,110	6,106	-5.6	2.7	16	$9,331	50.5	77.9	$37,758	0.0
Austin-Round Rock-San Marcos, TX	10,107	14,554	5.3	1.9	12	$10,414	38.9	65.3	$40,441	1.2
Bakersfield-Delano, CA	2,536	3,097	2.9	1.1	18	$6,226	47.1	65.6	$44,005	0.0
Baltimore-Towson, MD	18,927	22,619	2.6	1.7	16	$6,869	40.7	64.1	$44,569	0.5
Baton Rouge, LA	6,695	8,167	2.9	2.2	14	$29,918	40.2	63.0	$39,427	7.4
Birmingham-Hoover, AL	5,296	8,317	6.7	1.7	13	$16,609	47.8	71.0	$37,655	2.6
Boise City-Nampa, ID	5,433	7,456	4.6	2.8	17	$16,815	44.7	69.4	$36,139	1.6
Boston-Cambridge-Quincy, MA-NH	34,032	41,825	3.0	1.7	17	$17,184	42.6	63.8	$51,271	28.9
Bridgeport-Stamford-Norwalk, CT	5,198	6,266	2.7	1.5	19	$16,142	47.6	73.8	$44,251	4.7
Buffalo-Niagara Falls, NY	13,952	14,452	0.5	2.7	16	$5,831	46.8	73.9	$38,017	0.0
Cape Coral-Fort Myers, FL	1,496	2,235	5.9	1.1	10	$23,291	43.1	65.3	$37,131	0.0
Charleston-North Charleston-Summerville, SC	3,014	4,369	5.4	1.5	15	$34,605	45.1	67.8	$37,534	2.3
Charlotte-Gastonia-Rock Hill, NC-SC	11,217	15,485	4.7	1.9	13	$21,303	45.0	69.9	$40,858	10.1
Chattanooga, TN-GA	5,654	6,688	2.4	2.9	11.5	$18,776	49.4	75.8	$35,000	2.4
Chicago-Joliet-Naperville, IL-IN-WI	61,659	79,388	3.7	1.8	16	$25,002	45.3	70.1	$42,816	28.3
Cincinnati-Middletown, OH-KY-IN	14,804	18,525	3.3	1.9	16	$29,922	47.9	74.9	$37,991	2.6
Cleveland-Elyria-Mentor, OH	18,224	24,664	4.4	2.5	18	$33,682	48.1	74.2	$39,213	8.0
Colorado Springs, CO	1,287	1,934	6.0	0.7	16	$2,770	50.3	75.6	$37,605	0.0
Columbia, SC	8,099	8,568	0.8	2.4	16	$5,779	38.5	62.5	$38,621	0.0
Columbus, OH	11,231	15,498	4.7	1.7	18	$22,935	40.0	64.3	$42,340	10.3
Dallas-Fort Worth-Arlington, TX	30,658	38,562	3.3	1.3	14	$23,416	46.3	69.1	$40,105	28.1
Dayton, OH	4,263	6,232	5.6	1.6	16	$20,193	49.0	76.8	$37,574	0.0
Denver-Aurora-Broomfield, CO	20,214	27,929	4.7	2.3	13	$14,279	36.5	59.9	$47,602	8.0
Des Moines-West Des Moines, IA	2,472	5,256	11.4	1.6	15	$9,683	40.9	69.9	$38,671	0.0
Detroit-Warren-Livonia, MI	14,741	20,323	4.7	1.2	17	$21,218	45.0	69.2	$45,642	4.1
El Paso, TX	2,570	2,695	0.7	0.9	12.5	$13,915	46.7	72.2	$29,828	0.0
Fresno, CA	8,308	9,301	1.6	2.8	18	$12,041	47.8	65.0	$38,031	51.1
Grand Rapids-Wyoming, MI	17,232	8,812	-9.1	2.4	18	$39,631	52.4	74.4	$38,203	13.0
Greensboro-High Point, NC	5,086	5,725	1.7	1.7	15	$23,679	50.8	73.9	$35,381	7.6
Greenville-Mauldin-Easley, SC	7,247	10,127	4.9	3.4	14	$86,143	46.0	68.3	$38,193	1.7
Harrisburg-Carlisle, PA	9,091	13,025	5.3	4.0	12	$19,621	34.0	62.7	$43,224	0.0
Hartford-West Hartford-East Hartford, CT	8,812	13,712	6.5	2.2	14	$8,016	37.1	61.1	$48,757	10.8
Honolulu, HI	6,270	9,269	5.7	1.9	12.5	$5,161	42.7	68.1	$42,140	6.8
Houston-Sugar Land-Baytown, TX	27,855	39,986	5.3	1.6	13	$16,926	41.9	63.1	$42,779	74.0

Appendix C. The Aggregate Clean Economy in the 100 Largest Metropolitan Areas (continued)

Metropolitan Area	Jobs, 2003	Jobs, 2010	Annual average change in jobs, 2003-2010 (%)	Clean economy share of all metro jobs, 2010 (%)	Median age of establishment (in years) 2010	Exports per job, 2009	Share of jobs held by workers with a high school diploma or less, 2010 (%)	Share of jobs jobs that are green collar, 2010 (%)	Average annual wage, 2009	Share of establishments that are clustered, 2010 (%)
Indianapolis-Carmel, IN	13,574	15,183	1.6	1.7	15.5	$9,362	37.4	61.5	$41,245	0.0
Jackson, MS	3,370	4,298	3.5	1.7	14	$7,304	43.8	69.5	$32,888	0.0
Jacksonville, FL	5,940	7,679	3.7	1.3	13	$13,928	47.0	68.7	$37,040	4.2
Kansas City, MO-KS	19,832	25,039	3.4	2.5	18	$15,879	41.5	62.9	$42,870	6.8
Knoxville, TN	6,206	16,135	14.6	4.9	11	$20,107	28.1	37.7	$45,184	2.6
Lakeland-Winter Haven, FL	1,985	2,290	2.1	1.1	13	$25,218	48.8	71.9	$34,981	0.0
Las Vegas-Paradise, NV	6,672	9,797	5.6	1.2	9	$5,937	38.0	57.6	$46,590	13.8
Little Rock-North Little Rock-Conway, AR	5,916	11,934	10.5	3.4	14.5	$57,514	47.7	72.1	$33,857	13.2
Los Angeles-Long Beach-Santa Ana, CA	62,807	89,592	5.2	1.7	16	$18,449	46.7	70.9	$40,910	72.8
Louisville-Jefferson County, KY-IN	12,779	14,447	1.8	2.4	17	$36,817	51.5	76.1	$37,317	5.1
Madison, WI	9,215	12,337	4.3	3.5	17	$16,544	39.4	64.8	$43,466	12.2
McAllen-Edinburg-Mission, TX	1,243	2,203	8.5	1.0	11	$5,759	49.5	70.6	$27,981	0.0
Memphis, TN-MS-AR	8,719	11,515	4.1	1.9	13	$40,621	49.5	74.6	$36,138	7.5
Miami-Fort Lauderdale-Pompano Beach, FL	19,688	24,194	3.0	1.1	12	$9,155	42.2	66.6	$38,500	6.7
Milwaukee-Waukesha-West Allis, WI	13,516	13,471	0.0	1.6	19	$29,252	48.1	71.9	$41,031	3.9
Minneapolis-St. Paul-Bloomington, MN-WI	26,519	37,750	5.2	2.2	17	$15,608	45.0	69.5	$44,388	15.8
Modesto, CA	2,974	2,688	-1.4	1.7	18	$10,017	53.9	61.4	$39,279	0.0
Nashville-Davidson--Murfreesboro--Franklin, TN	11,211	17,913	6.9	2.4	13	$17,026	41.3	67.9	$37,705	0.0
New Haven-Milford, CT	4,711	5,636	2.6	1.6	19	$17,974	47.4	72.2	$42,985	13.8
New Orleans-Metairie-Kenner, LA	8,385	7,298	-2.0	1.4	15	$5,604	43.5	70.9	$38,183	0.0
New York-Northern New Jersey-Long Island, NY-NJ-PA	104,185	152,034	5.5	1.8	18	$10,251	47.0	74.4	$45,586	10.8
North Port-Bradenton-Sarasota, FL	2,095	2,409	2.0	1.0	14	$22,719	45.7	70.9	$36,499	0.0
Ogden-Clearfield, UT	1,184	2,111	8.6	1.0	13	$4,657	40.7	62.3	$39,615	0.0
Oklahoma City, OK	4,833	6,854	5.1	1.2	17	$6,716	40.5	67.2	$35,559	0.0
Omaha-Council Bluffs, NE-IA	4,954	7,406	5.9	1.6	18	$11,663	45.0	67.8	$38,057	10.4
Orlando-Kissimmee-Sanford, FL	7,132	11,033	6.4	1.1	14	$11,654	45.3	69.7	$36,408	0.0
Oxnard-Thousand Oaks-Ventura, CA	4,344	5,246	2.7	1.7	18	$21,007	46.6	59.8	$44,449	14.3
Palm Bay-Melbourne-Titusville, FL	6,204	3,446	-8.1	1.7	14	$5,568	42.8	71.0	$37,931	0.0
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	47,752	54,325	1.9	2.0	17	$15,693	45.5	70.3	$43,913	7.6
Phoenix-Mesa-Glendale, AZ	18,814	22,904	2.9	1.3	13	$14,390	45.1	71.1	$38,980	18.6
Pittsburgh, PA	17,025	21,963	3.7	1.9	17	$13,257	46.7	71.9	$37,906	35.9
Portland-South Portland-Biddeford, ME	2,692	3,591	4.2	1.3	18	$12,662	46.8	69.8	$37,612	0.0
Portland-Vancouver-Hillsboro, OR-WA	20,792	27,489	4.1	2.7	18	$13,952	45.0	69.0	$42,548	7.5
Poughkeepsie-Newburgh-Middletown, NY	2,139	2,951	4.7	1.1	17	$6,096	46.0	70.2	$41,635	0.0
Providence-New Bedford-Fall River, RI-MA	11,709	12,904	1.4	1.9	14	$24,971	46.2	71.1	$40,036	0.0
Provo-Orem, UT	1,406	1,587	1.7	0.8	14.5	$18,767	43.4	66.7	$33,374	0.0
Raleigh-Cary, NC	6,788	16,677	13.7	3.3	13	$5,867	37.0	64.0	$40,795	21.9
Richmond, VA	7,723	10,630	4.7	1.7	15	$20,896	45.1	72.8	$40,365	2.6

Appendix C. The Aggregate Clean Economy in the 100 Largest Metropolitan Areas (continued)

Metropolitan Area	Jobs, 2003	Jobs, 2010	Annual average change in jobs, 2003-2010 (%)	Clean economy share of all metro jobs, 2010 (%)	Median age of establishment (in years) 2010	Exports per job, 2009	Share of jobs held by workers with a high school diploma or less, 2010 (%)	Share of jobs jobs that are green collar, 2010 (%)	Average annual wage, 2009	Share of traded sector establishments that are clustered, 2010 (%)
Riverside-San Bernardino-Ontario, CA	17,172	22,532	4.0	1.9	16	$14,924	45.3	65.2	$41,248	15.1
Rochester, NY	7,061	8,385	2.5	1.6	15	$17,289	50.1	75.3	$36,699	0.0
Sacramento--Arden-Arcade--Roseville, CA	23,462	37,319	6.9	4.5	14	$4,975	34.4	62.0	$49,589	34.7
Salt Lake City, UT	7,412	10,539	5.2	1.7	15.5	$13,374	47.6	75.3	$36,251	6.5
San Antonio-New Braunfels, TX	7,938	10,634	4.3	1.2	14	$6,764	47.1	72.4	$34,195	0.0
San Diego-Carlsbad-San Marcos, CA	14,337	22,862	6.9	1.7	15	$17,114	43.3	66.0	$45,016	56.5
San Francisco-Oakland-Fremont, CA	36,027	51,811	5.3	2.1	15	$20,705	37.1	54.7	$59,856	23.3
San Jose-Sunnyvale-Santa Clara, CA	19,360	18,868	-0.4	2.2	12.5	$38,521	44.9	66.6	$55,827	37.1
Scranton--Wilkes-Barre, PA	3,464	4,437	3.6	1.7	18	$10,094	47.5	71.6	$34,780	0.0
Seattle-Tacoma-Bellevue, WA	21,760	31,340	5.3	1.8	16	$10,369	44.1	65.3	$49,128	44.8
Springfield, MA	7,235	10,443	5.4	3.5	17	$4,079	39.1	68.1	$42,657	0.0
St. Louis, MO-IL	15,836	17,553	1.5	1.3	17	$29,792	45.8	68.5	$41,968	3.8
Stockton, CA	3,390	4,642	4.6	2.2	16	$17,374	49.4	75.0	$40,437	0.0
Syracuse, NY	8,272	9,648	2.2	3.0	15	$10,317	46.7	74.4	$39,254	8.5
Tampa-St. Petersburg-Clearwater, FL	10,733	15,347	5.2	1.3	14.5	$11,603	44.3	68.6	$37,300	0.0
Toledo, OH	6,873	11,831	8.1	3.9	16	$25,371	41.7	61.0	$40,276	11.5
Tucson, AZ	3,556	5,327	5.9	1.5	18	$12,627	40.2	63.1	$38,838	9.5
Tulsa, OK	4,076	7,130	8.3	1.7	16	$9,457	43.8	72.6	$34,079	0.0
Virginia Beach-Norfolk-Newport News, VA-NC	8,065	9,594	2.5	1.1	13	$4,883	46.2	72.3	$38,171	0.0
Washington-Arlington-Alexandria, DC-VA-MD-WV	50,425	70,828	5.0	2.3	13	$6,183	37.2	62.3	$51,651	19.8
Wichita, KS	2,811	3,913	4.8	1.3	16	$27,177	47.6	71.6	$36,124	8.3
Worcester, MA	4,914	6,537	4.2	2.0	18	$24,177	47.3	74.0	$41,788	3.2
Youngstown-Warren-Boardman, OH-PA	2,192	2,977	4.5	1.3	15	$4,402	48.3	75.1	$34,923	0.0
100 Largest Metro Areas	**1,276,388**	**1,705,897**	**4.2**	**1.9**	**15**	**$17,255**	**43.6**	**67.7**	**$43,133**	**18.8**

Source: Brookings-Battelle Clean Economy Database; exports: Brookings analysis of U.S. International Trade Commission, Bureau of Economic Analysis, Internal Revenue Service, Institute of International Education, and Moody's Analytics data; educational attainment: U.S. Bureau of Labor Statistics Employment Projections Program; green collar jobs: U.S. Bureau of Labor Statistics Occupational Employment Statistics and Employment Projections Program; wages: U.S. Bureau of Labor Statistics Occupational Employment Statistics; clusters: Brookings analysis (see methods external appendix for details).

**State and metro clustering figures exclude non-exporting segments, defined as those with less than $4000 in exports per job.*

Appendix D. The Clean Economy by Industry (NAICS-Based)

NAICS Code	Industry Title	Jobs, 2010	Share of all clean economy jobs, 2010 (%)
11	Agriculture, Forestry, Fishing and Hunting	31,373	1.2
21	Mining, Quarrying, and Oil and Gas Extraction	1,091	0.0
22	Utilities	155,875	5.8
23	Construction	106,109	4.0
31-33	Manufacturing	687,116	25.7
42	Wholesale Trade	157,476	5.9
44-45	Retail Trade	15,977	0.6
48-49	Transportation and Warehousing	341,041	12.7
51	Information	657	0.0
52	Finance and Insurance	565	0.0
53	Real Estate and Rental and Leasing	718	0.0
54	Professional, Scientific, and Technical Services	278,621	10.4
55	Management of Companies and Enterprises	453	0.0
56	Administrative and Support and Waste Management and Remediation Services	299,409	11.2
61	Educational Services	520	0.0
62	Health Care and Social Assistance	2,115	0.1
71	Arts, Entertainment, and Recreation	253	0.0
72	Accommodation and Food Services	314	0.0
81	Other Services (except Public Administration)	21,067	0.8
92	Public Administration	574,795	21.5

Source: Brookings-Battelle Clean Economy Database

Appendix E. Occupations of the Clean Economy

Occupational Title	Median annual wage, 2009	Share of all clean economy occupations (%)	Share of all U.S. occupations (%)	Share of workers in occupation with with high school diploma or less (%)
High-wage occupations				
Management	$89,330	5.7	4.7	4.7
Legal	$74,030	0.7	0.8	2.7
Computer & math	$72,900	2.1	2.5	1.2
Architecture & engineering	$68,790	5.7	1.8	2.4
Business & financial	$58,910	5.8	4.6	2.1
Life, physical, & social science	$58,300	2.3	1.0	3.3
Healthcare practitioner & technical	$57,690	1.2	5.5	1.2
Education, training, & library	$45,210	0.4	6.5	2.0
Arts, design, entertainment, sports, & media	$42,450	0.6	1.3	4.8
All high-wage occupations	*$63,068*	*24.4*	*28.8*	*2.8*
Middle-wage occupations				
Installation, maintenance, and repair occupations	$39,600	6.2	3.9	27.6
Community and social services occupations	$38,970	1.4	1.4	3.3
Construction and extraction occupations	$38,770	7.2	4.4	51.9
Protective service occupations	$36,170	4.5	2.4	10.5
Office and administrative support occupations	$30,410	14.1	17.1	10.2
Production occupations	$29,970	15.9	6.8	44.2
Transportation and material moving occupations	$28,010	19.3	6.8	43.3
All middle-wage occupations	*$34,557*	*68.7*	*42.9*	*26.5*
Low-wage occupations				
Healthcare support occupations	$24,720	0.3	3.0	23.2
Sales and related occupations	$23,940	3.4	10.5	17.7
Building and grounds cleaning and maintenance occupations	$22,350	0.9	3.3	66.6
Personal care and service occupations	$20,770	1.2	2.6	23.7
Farming, fishing, and forestry occupations	$19,610	0.7	0.3	18.2
Food preparation and serving related occupations	$18,490	0.4	8.6	49.6
All low-wage occupations	*$21,647*	*6.9*	*28.3*	*34.2*

Source: Brookings analysis of the Brookings-Battelle Clean Economy Database and industry-occupation estimates from the U.S. Bureau of Labor Statistics' Occupational Employment Statistics (OES) and Employment Projections programs. Occupations were estimated based on 4-digit NAICS codes. Missing data (for the public sector and agricultural workers) were supplemented using the 2009 American Community Survey--accessed through Integrated Public Use Microdata Series (IPUMS) Version 4.0. The rows with category totals display the sum of the percentages and the average of the median wages and educational requirements. See external methods appendix for more details.

ENDNOTES

CHAPTER 1

1. See Allison Hannon and others, "Delivering Low Carbon Growth: A Guide to China's 12th Five-Year Plan" (London: Climate Group and HSBC, 2011).
2. Chico Harlan, "Japan Takes a Shine to Renewable Energy," *The Washington Post*, May 27, 2011.
3. "UK Outlines Plans for Green Bank," *The Associated Press*, May 23, 2011.
4. Data here and in the following passage on world clean energy investments come from *Bloomberg New Energy Finance*. For background on the international clean energy "race" see Pew Charitable Trusts, "Who's Winning the Clean Energy Race? 2010 Edition: G-2: Investment Powering Forward" (Washington: 2011).
5. Andrew Liveris, *Make It in America: The Case for Re-Inventing the Economy* (Hoboken: John Wiley & Sons, 2011).
6. The most notable and comprehensive cross-sectional study to date remains the 50-state comparative research Collaborative Economics performed for the Pew Charitable Trusts. See The Pew Charitable Trusts, "The Clean Energy Economy: Repowering Jobs, Businesses, and Investments Across America" (Washington: 2009).

CHAPTER 2

1. For important reviews of the environmental, security, and economic challenges associated with the world's present development path, with a focus on the energy portion of the "green" concern, see Michael Greenstone and Adam Looney, "A Strategy for America's Energy Future: Illuminating Energy's Full Costs" (Washington: Hamilton Project/ Brookings Institution, 2011) and Jason Furman and others, "An Economic Strategy to Address Climate Change and Promote Energy Security" (Washington: Hamilton Project/Brookings Institution, 2007).
2. United Nations Environment Program, "Global Environmental Outlook 4" (New York: 2007). United Nations Environment Program, "Towards a Green Economy" (Paris: 2011). Deutsche Bank Climate Change Advisors, "Investing in Climate Change 2010: A Strategic Asset Allocation Perspective" (New York: January 2010).
3. United Nations Department of Economic and Social Affairs, "World Population Prospects: The 2010 Revision" (New York: 2011).
4. United Nations Environment Programme, "Global Environmental Outlook 4." United Nations Water, "World Water Development Report: Water for a Changing World" (New York: 2009). Available at www.unesco.org/water/wwap/wwdr/wwdr3/
5. Deutsche Bank Research, "World Water Markets 2010" (Frankfurt, 2010).
6. McKinsey & Company, "Charting Our Water Future" (2009). Available at http://www.mckinsey.com/App_Media/Reports/Water/Charting_Our_Water_Future_Full_Report_001.pdf .
7. On the growing world energy demand see Energy Information Administration, "International Energy Outlook 2010" (Washington: 2010). In its "World Energy Outlook 2010," the International Energy Agency predicts that energy demand will increase more slowly, by 36 percent from 2008 to 2035, if countries act on their Copenhagen commitments.
8. National Academy of Sciences, "Advancing the Science of Climate Change" (Washington: National Academies Press, 2010). National Academy of Sciences, "America's Climate Choices" (Washington: National Academies Press, 2011). There remains broad-based scientific and political consensus that climate change is occurring and that increases in atmospheric greenhouse gas (GHG) concentrations are driving it.
9. Emissions targets submitted to the United Nations Framework Convention on Climate Change (UNFCCC) for industrialized (Annex I countries) countries can be found here: http://unfccc.int/home/items/5264.php; nationally appropriate mitigation actions committed to by developing (non-Annex I) countries can be found here: http://unfccc.int/home/items/5265.php. See also William Antholis, "International global energy diplomacy built on domestic action: A" in William Antholis and Charles Ebinger, "The Status Report: Obama and Energy Security," *Up Front Blog*, Brookings Institution, January 5, 2011. For background on the difficulty of comparing the often ambiguous national emissions reduction commitments made in the Copenhagen Accord see Warwick McKibben, Adele Morris, and Peter Wilcoxen, "Comparing Climate Commitments: A Model-Based Analysis of the Copenhagen Accord" (Washington: Brookings Institution, 2010). To be sure these commitments are insufficient by themselves to reduce global emissions by the 50 to 80 percent from 2005 levels estimated to be needed to limit global average temperature increase to an acceptable 2.4 degrees Celsius. For an analysis of the pledges' insufficient contributions to needed long-term emissions reductions see United Nations Environment Programme, "The Emissions Gap Report: Are the Copenhagen Accord Pledges Sufficient to Limit Global Warming to 2°C or 1.5°C?" (2010).
10. Deutsche Bank Climate Change Advisors, "Investing in Climate Change 2011" (Frankfurt am Main, 2011). See also Deutsche Bank Climate Change Advisors, "Investing in Climate Change 2010" which notes that though while the Copenhagen meeting did not deliver a legally binding global deal to curb emissions it "shifted the focus to countries taking action and reporting it individually."
11. Bernard Sinclair-Desgagné, "The Environmental Goods and Services Industry" (Montreal: HEC Montréal, CIRANO, CIRAIG, 2008). See also: Pew Charitable Trusts, "Global Clean Power: A$2.3 Trillion Opportunity" (Washington, 2010).
12. Sarah Ladislav and others, "A Roadmap for a Secure, Low Carbon Energy Future" (Washington: World Resources Institute and Center for Strategic and International Studies, 2010).
13. Energy Information Administration, "Monthly Energy Review April 2011" available at (May 2011) www.eia.gov/petroleum/data.cfm#summary.
14. Michael Greenstone and Adam Looney, "A Strategy for America's Energy Future."
15. See also, on energy security challenges more generally, Sarah Ladislaw, Kathryn Zyla, and Britt Childs, "Managing the Transition to a Secure, low-Carbon Energy Future" (Washington: Center for Strategic and International Studies and World Resources Institute, 2008).
16. A large body of economics research finds that oil price shocks and higher electricity prices each have large and negative effects on U.S. gross domestic product. See Jason Furman and others, "An Economic Strategy to Address Climate Change and Promote Energy Security" as well as James D. Hamilton, "Oil and the Microeconomy." (La Jolla, CA: University of California, San Diego, August 2005) and Donald W. Jones, Paul Leiby, and Inja Paik, "Oil Price Shocks and the Macroeconomy: What Has Been Learned Since 1996." *The Energy Journal* 25 (2) (2004): 1-32.
17. CNA Corporation, "National Security and the Threat of Climate Change" (Alexandria, Virginia: 2007). Dennis Blair, "Annual Threat Assessment of the U.S. Intelligence Community" (Testimony before the U.S. Senate Select Committee on Intelligence: February 2, 2010).
18. For background on the demand for water treatment technologies and services being driven by shale gas mining in Pennsylvania see Maria Gallucci, "Water Treatment Firms See Boom in Business as Gas Drilling Spreads." *SolveClimate News*, May 23, 2011.
19. CNA Corporation, "National Security and the Threat of Climate Change." The United Nations projects that developing countries, where access to clean water and basic sanitation are already poor, will shelter 90 percent of the 3 billion people the planet will add through 2050. For additional information see: UN Water, "World Water Development Report 3."
20. UN Water, "World Water Development Report 3."
21. McKinsey & Company, "Charting Our Water Future."
22. Mia Javier, "The Promise of Water Innovation" *Cleantech Investment Insights*, a blog of the Cleantech Group, May 13, 2011, available at http://blog.cleantech.com/cleantech-investments/the-promise-of-water-innovation/. See also DB Climate Change Advisors, "Investing in Climate Change 2011" and McKinsey & Company, "Charting Our Water Future."
23. Some conventional economists still view capital accumulation as the key to growth. However, in recent years, a growing number of economists have come to conclude that it is not so much the accumulation of more savings or capital that is the key to improving standards of living in developed countries; rather it is innovation. For such views see: Robert Solow, "Technical Change and the Aggregate Production Function," *The Review of Economics and Statistics* 39 (3) (1957): 312-320; Paul Romer, "Endogenous Technological Change," *Journal of Political Economy* 98 (5) (1990): 71-102; Gregory N. Mankiw, David Romer, and David N. Weil, "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics* 107 (2) (1992): 407-437; Robert E. Hall and Charles I. Jones, "Why do Some Countries Produce So Much More Output per Worker than Others?" *The Quarterly Journal of Economics* 114 (1) (1999): 83-116; and Elhanan Helpman, *The Mystery of Economic Growth* (Cambridge, MA: Belknap Press, 2004.
24. World Economic Forum, "Green Investing 2011" (Geneva: 2011).
25. Ernst & Young, "Cleantech Matters: Global Cleantech Insights and Trends, 2011" (London: 2011).
26. Mia Javier, "State of Water Innovation" (San Francisco: Cleantech Group, 2010) and Deutsche Bank Research, "World Water Markets 2010."
27. Stuart J.H. Graham, Robert Merges, Pam Samuelson, and Ted Sichelman "High Technology Entrepreneurs and the Patent System: Results of the 2008 Berkeley Patent Survey," *Berkeley Technology Law Journal* 24 (4) (2010): 1248-1318; Bronwyn H. Hall and Josh Lerner, "The Financing of R&D and Innovation." In B. Hall and N. Rosenberg eds., *Handbook of the Economics of Innovation*, (Elsevier-North Holland: 2010). The reason for the patent intensity of VC-backed firms appears to be the fact that venture-capitalists screen firms and their technologies very carefully and then closely monitor and try to improve their performance as the firm develops its product.
28. PricewaterhouseCoopers / National Venture Capital Association MoneyTree Report, Data: Thomson Reuters, available at www.nvca.org/
29. Ernst and Young, "From Survival to Growth: Global Venture Capital Insights and Trends Report 2009" (2009). Deloitte and National Venture

Capital Association, "2010 Global Trends in Venture Capital: Outlook for the Future" (2010).

30. OECD, "Indicator of environmental technologies (ENV-tech)" (2010), available at www.oecd.org/environment/innovation.

31. For discussions of nations' efforts to establish competitive advantage in clean economy manufacturing capacity, the deployment of clean energy technologies, and enabling infrastructure see Rob Atkinson and others, "Rising Tigers, Sleeping Giant: Asian Nations Set To Dominate the Clean Energy Race by Out-Investing the United States" (Washington and Oakland: Information Technology and Innovation Foundation and Breakthrough Institute, 2009) and Pew Charitable Trusts, "Who's Winning the Clean Energy Race? 2010 Edition."

32. Alan Berube and others, "MetroNation: How U.S. Metropolitan Areas Fuel American Prosperity" (Washington: Brookings Institution, 2007).

33. Mark Muro and others, "MetroPolicy: Shaping a New Federal Partnership for a Metropolitan Nation" (Washington: Brookings Institution, 2008).

34. Brookings analysis of Census Bureau American Community Survey data (2009); Brookings analysis of U.S. Geological Survey data (2005); Brookings analysis of Department of Transportation Highway Performance Monitoring System data (2006); Marilyn Brown and others, "Shrinking the Carbon Footprint of Metropolitan America." (Washington: Brookings Institution, 2008).

35. Brookings analysis of data from the U.S. Green Building Council.

36. National Research Council Committee on an Assessment of Research Doctorate Programs, "A Data-Based Assessment of Research-Doctorate Programs in the United States" (Washington: The National Academy of Sciences, 2010), available at http://www.nap.edu/rdp. Brookings analysis of U.S. Census Bureau American Community Survey 2009 data.

37. Brookings analysis of data from ARPA-E.

38. The three programs administered by the Department of Energy Office of Loans are Section 1703, which guarantees loans for projects that employ new or significantly improved energy technologies to avoid, reduce, or sequester air pollutants or greenhouse gases; Section 1705, part of the Recovery Act, which guarantees loans for certain clean energy projects that commence construction on or before September 30, 2011; and the Advanced Technology Vehicles Manufacturing program, which provides direct loans to finance advanced vehicle technologies. See https://lpo.energy.gov/?page_id=2.

39. Alan Berube and others, "MetroNation." Research from the Federal Reserve Bank of Philadelphia, for instance, notes that patents not only proliferate markedly with increased employment density but tend to be cited within the same metropolitan area. See Gerald Carlino, Satyajit Chatterjee, and Robert Hunt, "Urban Density and the Rate of Invention," Working Paper 04-16/R (Federal Reserve Bank of Philadelphia, 2006). For more on the association of clusters with innovation, see Maryann Feldman, *The Geography of Innovation* (Dordrecht: Kluwer Academic Publishers, 1994) and David Audretsch and Maryann Feldman, "The New Economics of Innovation, Spillovers, and Agglomeration: A Review of Empirical Studies." In Gordon L. Clark, Maryann Feldman, and Meric Gertner, eds., *The Oxford Handbook of Economic Geography* (New York: Oxford University Press, 2002).

40. For background on the relationship between firm growth and regional character see Zoltan Acs and Pamela Mueller, "Employment effects of business dynamics: Mice, Gazelles and Elephants," *Small Business Economics* 30 (2008): 85-100. For the Global Cleantech 100 list see www.guardian.co.uk/globalcleantech100/cleantech-100-2010-list?CMP=twt_gu For a dot map of the world location of the 100 Cleantech 100 firms go here: http://www.guardian.co.uk/globalcleantech100/interactive/world-map For two blogs on the metropolitan clustering of U.S. Global Cleantech 100 firms see Jonathan Rothwell and Mark Muro, "Where the Cleantech Companies Are," The Avenue, a blog of *The New Republic*, February 23, 2011 and Jonathan Rothwell and Mark Muro, "Top of the Class: The Role of Leading Academic Programs in Cleantech Innovation," The Avenue, a blog of *The New Republic*, February 24, 2011.

41. Alan Berube and others, "MetroNation."

CHAPTER 3

1. Index to the Digest of Green Reports and Studies, available at www.labormarketinfo.edd.ca.gov/contentpub/GreenDigest/Green-Digest-Index.pdf (February 2011).

2. "Global Metro Summit 2010: Delivering the Next Economy," available at www.brookings.edu/events/2010/1208_metro_summit.aspx. Emilia Istrate, Jonathan Rothwell, and Bruce Katz, "Export Nation: How U.S. Metros Lead National Export Growth and Boost Competitiveness" (Washington: Brookings Institution, 2010).

3. Eurostat, "Handbook on the Environmental Goods and Services Sector" (Luxembourg, 2009); U.S. Census Bureau, "Survey of Environmental Products and Services" (Washington: Environmental Protection Agency, 1998); Organization for Economic Cooperation and Development, "The Environmental Goods and Services Industry: Manual for Data Collection and Analysis" (Paris, 1999); U.S. Bureau of Labor Statistics Federal Register Notice 75 (182) (September 21, 2010) www.bls.gov/green/frn_2010_09_21.pdf

4. Readers interested in these jobs can look forward to the Bureau of Labor Statistics survey, which will aim to measure the clean economy and clean process economy in two separate surveys.

5. Eurostat, "Handbook on the Environmental Goods and Services Sector"; U.S. Census Bureau, "Survey of Environmental Products and Services"; OECD, "The Environmental Goods and Services Industry"; BLS, Federal Register Notice 75.

6. Since 1990, the firm Dun & Bradstreet has aimed to create a census of U.S. establishments and their employees. They used the SIC system to classify firms, and found that they needed to expand the number of digits from six to eight to account for new industries. In 1997, the federal government moved to the NAICS, but Dun & Bradstreet kept the older system that they had developed. Walls & Associates has developed a "cross-walk" between D&B's SIC and the contemporary NAICS, which was used in this report.

7. Karen Chapple and Malo Hutson, "Innovating the Green Economy in California Regions" (Berkeley: University of California Center for Community Innovation, 2010). Available at http://communityinnovation.berkeley.edu/publications.html

8. Some industries—such as urban planning and bicycle repair—were not included in this study because the environmental benefit was unclear. Likewise, some companies appeared to have been mis-classified, and so they were excluded.

9. The Pew Charitable Trusts, "The Clean Energy Economy." Pew found that 60 percent of clean economy jobs are in establishments from these industries.

10. The following changes were made to the BLS categories: Public awareness was dropped from the category "Education and Compliance" (and considered here as a clean economy "process job" rather than a production job); "Energy Efficiency" was broadened to include resource efficiency (e.g. water); Agriculture was added to "Natural Resources Conservation;" and "Pollution Reduction and Removal" was changed to "Environmental Management."

11. For example, if a company was listed by the American Wind Energy Association, it was placed in "Wind Energy." All USDA certified farmers were classified in "Organic Farms and Organic Food Production." In other cases, the product—such as vehicle batteries—was used to make the classification.

12. BLS Business Employment Dynamics, available at www.bls.gov/bdm/home.htm (2011).

13 Istrate, Rothwell, and Katz, "Export Nation."

14. See www.bls.gov/oes/oes_dl.htm#2009; http://www.bls.gov/emp/ep_table_111.htm#1

15. Elliot Martin and others, "Impact of Carsharing on Household Vehicle Holdings: Results from North American Shared-Use Vehicle Survey," *Transportation Research Record* 2143 (2010): 150-158.

16. Ibid.

17. Tai Stillwater and others, "Carsharing and the Built Environment: A Geographic Information System-Based Study of One U.S. Operator," *Transportation Research Record* 2110 (2009): 27-34.

18. Oregon Employment Department, "The Greening of Oregon's Workforce: Jobs, Wages, and Training" (2009); California Employment Development Department, "California's Green Economy" (2010); Nicholas Jolly, "How Green is Connecticut's Economy?" *The Connecticut Economic Digest* 13 (12) (2008): 1-3. The green jobs number in California refers to the number of employees who report spending most of their time on green aspects of job (263,000).

19. Washington State Employment Security Department, "2008 Washington State Green Economy Jobs" (2009); Washington State Employment Security Department, "2009 Washington State Green Economy Jobs" (2010).

20. Missouri Economic Research and Information Center, "The Missouri Green Jobs Report" (2009); Kansas Department of Labor, "2009 Kansas Green Jobs Report" (2010).

21. Michigan Department of Energy, Labor & Economic Growth, "Michigan Green Jobs Report: Occupations & Employment in the New Green Economy" (2009).

22. The Pew Charitable Trusts, "The Clean Energy Economy"; U.S. Department of Commerce, Economics and Statistics Administration, "Measuring the Green Economy" (Washington, 2010) U.S. International Trade Administration, Office of Energy and Environmental Industries, "Environmental Technologies Industries: 2010 Industry Assessment" (2010); U.S. Conference of Mayors, "U.S. Metro Economies: Current and Potential Green Jobs in the U.S. Economy" (2009); The Center for Community Innovation, "Innovating the Green Economy in California Regions" (2010).

23. See the Solar Energy Industries Association website, available at http://seia.org/galleries/default-file/2009%20Solar%20Industry%20Year%20in%20Review.pdf

24. See the Solar Foundation website, available at http://www.thesolarfoundation.org/sites/thesolarfoundation.org/files/Final%20TSF%20National%20Solar%20Jobs%20Census%202010%20Web%20Version.pdf

25. See the National Hydropower Association website, available at http://hydro.org/wp-content/uploads/2011/02/NHA-Annual-Conf-Frantzis-pres-Final-7.pdf

26. See the American Wind Industry Association website, available at www.awea.org/_cs_upload/learnabout/publications/5094_1.pdf

27. See the Geothermal Energy Association website, available at http://geo-energy.org/geo_basics_employement.aspx

28. "Global Cleantech 100," *The Guardian*, available at http://www.guardian.co.uk/globalcleantech100/cleantech-100-2010-list?CMP=twt_gu (January 2011).

CHAPTER 4

1. The figure is for 2010, and the source is Moody's Economy.com. NAICS 621, 622, and 623 were included. Social assistance was excluded.

2. Brookings analysis of 2009 Census County Business Patterns data shows that jobs associated with producing fossil fuel based energy, derivative products, and machinery make up roughly one percent of the U.S. economy. If one adds distribution, gas stations, fuel transportation, and wholesalers–peripheral activities excluded from the clean economy estimates–the fossil fuel economy still employs only 1.8 percent of U.S. workers or 2.4 million workers. A 2009 report from Pricewaterhouse Coopers estimated that the number of jobs directly involved in the fossil fuel industry was 2.1 million; that report was commissioned by the American Petroleum Institute. (See Pricewaterhouse Coopers, "The Economic Impacts of the Oil and Natural Gas Industry on the U.S. Economy: Employment, Labor Income and Value Added" (2009).

3. Battelle and Biotechnology Industry Organization, "State Bioscience Initiatives 2010" (2010).

4. The source of these data is Moody's Economy.com special aggregates, IT-Producing Industries. Estimates are for 2010.

5. See the *GoodGuide*, available at www.goodguide.com/about/methodology. *GoodGuide* is a "for benefit" corporation, or B Corporation.

6. Growth data here refer to job gains from openings and expansions, as well as job losses from contractions. They exclude job losses from the closing of establishments, because that data was not available for the clean economy. The national data also excludes jobs lost from closings to create a comparable set of businesses. This can be done by subtracting the number of deaths over the period (2003 to 2010) from the base year (2003). This creates a universe of survivors. The underlying national data is from the Bureau of Labor Statistics' Business Employment Dynamics series.

7. John C. Haltiwanger, Ron S. Jarmin, and Javier Miranda, "Who Creates Jobs? Small Vs. Large Vs. Young," Working Paper 16300 (National Bureau of Economic Research, 2009).

8. The median year of establishment birth in the clean economy is 1995. Analysis of Business Dynamics Statistics and the Bureau of Employment Dynamics data show that the average year of establishment birth is between 1994 and 1997 for the U.S. economy. Start years for the hydropower segment were missing for all but three observations out of 1400 establishments. The median start year for those three was 1990. Caution should be used in interpreting these figures. The true median start year is probably earlier. However, the Federal Energy Regulatory Commission database reports the date of licenses issued to hydroelectric producers. The median year for these licenses is also 1990. See www.ferc.gov/industries/hydropower.asp

9. See the external methods appendix for details. These figures reflect Brookings analysis of data from the BLS's Business Employment Dynamics series. All subsequent deaths were subtracted from the base year to account for job losses due to closings and make the data comparable to the clean economy. Nationally, old establishments–born before 2003–lost jobs at a rate of -0.5 percent per establishment per year.

10. Data on U.S. manufacturing from Moody's Economy.com. This number is the sum of manufacturing employment in the 50 states, not for the United States and its territories.

11. These data are from the BLS Business Employment Dynamics program. The 3.3 million figure is net of openings, expansions, contractions, and closings. The comparable number to the clean economy would be 1.3 million losses–that excludes job losses from establishments that closed.

12. These data are estimated based on a technique described in the methods section and external methods appendix. It estimates exports at the establishment level based on the establishment's industry. However, the use of an alternative method to estimate exports yields similar results. Evidence from the International Trade Administration (ITA) paints an encouraging picture on exports in the clean economy–which is associated with environmental technologies. According to a Brookings analysis of an ITA list of 228 products deemed to be environmental technologies, the United States exports 60 percent more in environmental goods than it imports. Moreover, the share of U.S. manufacturing exports from environmental technologies increased from 2.9 in 1996 to 4.5 in 2009. Overall, the definition used by the ITA is very similar to the Brookings definition used here. Employing the ITA's product codes, the value of environmental exports–excluding services–comes to almost $40 billion in 2010.

13. Randy A. Becker and Ronald J. Shadbegian, "Environmental Products Manufacturing: A Look Inside the Green Industry," *The B.E. Journal of Economic Analysis and Policy* 9 (1) (2009): 1-23.

14. All the growth figures here exclude establishments that may have closed between 2003 and 2010.

15. Gilles Duranton and Diego Puga, "Nursery Cities: Urban Diversity, Process Innovation, and the Life Cycle of Products," *American Economic Review* 91 (5) (2001): 1454-1477.

16. This excludes establishments that may have closed in intervening years.

17. Exporting establishments are defined as those with above average exports per worker, meaning above $20,000.

18. Details describing how this result was obtained are discussed in the external methods appendix. To summarize, establishment level employment growth was regressed on establishment characteristics including age, headquarters status, branch status, three-digit industry, county level employment, company level employment, the number of establishments in the company, and county level segment employment in other establishments. Errors were allowed to cluster at the county level.

19. Methodologically, establishments were defined as concentrated in clusters if other establishments in the same county comprised at least 1 percent of all U.S. employment for the given segment in the base year of 2003. By this standard, 47.3 percent of all establishments were in clusters. The results are not substantially changed if the definition is relaxed or made more discriminating. Using a threshold of 0.01 percent for the county share of U.S. employment, which includes 73 percent of all establishments, clustered establishments grew at 4.6 percent on average, compared to 3.2 percent for isolated establishments. Using a stricter threshold of 1 percent, which applies to just 11 percent of establishments in the clean economy, those that were clustered grew at a rate of 5.3 percent, compared to 3.4 percent for non-clustered establishments. In other words, using any reasonable definition of concentration, clean economy establishments benefitted from being located in concentrated clusters of peer establishments in the same segment.

20. See, among others, J. Vernon Henderson, "Marshall's Scale Economies," *Journal of Urban Economics* 53 (2003): 1-28; Stuart Rosenthal and William Strange, "Evidence on the Nature and Sources of Agglomeration Economies," in J.V. Henderson and J. F. Thisse, eds., *Handbook of Regional and Urban Economics*, vol. 4 (Amsterdam: North-Holland, 2004); Gilles Duranton, Philippe Martin, Thierry Mayer and Florian Mayneris, The Economics of Clusters: Lessons from the French Experience (Oxford: Oxford University Press, 2010). Clusters benefit economic performance through three mechanisms, according to the work of Giles Duranton and colleagues: sharing, learning, and matching. Sharing is facilitated in clusters in that proximity allows firms to share things like facilities, transportation infrastructure, and even institutions (like universities or federal labs). Clusters may reduce the costs of establishing or maintaining these valuable resources. Learning is facilitated in clusters through knowledge diffusion, which has proven to be easier over short distances, whether it be via teaching, casual conversation, or employees transferring to rival firms or starting-up their own. Finally, clusters can improve matching between workers and employers or suppliers and buyers. (For details see: Peter Thompson, "Patent Citations and the Geography of Knowledge Spillovers: What do Patent Examiners Know?" *The Review of Economics and Statistics* 88 (2) (2006): 383-388; Matt Marx, Deborah Strumsky, Lee Fleming, "Mobility, Skills, and the Michigan Non-Compete Experiment," *Management Science* 55 (6) (2009): 875-889; Toby Stuart and Olav Sorenson, "Liquidity Events, Noncompete Covenants, and the Geographic Distribution of Entrepreneurial Activity," *Administrative Science Quarterly* 48 (2003): 175-201.

21. That calculation takes (1130/190)^0.03, where 0.03 is the coefficient on cluster size for a regression of the log of 2003 jobs at an establishment on the log of county level employment of other establishments in the same segment. See the external methods appendix for details.

22. Zoltan J. Acs and Pamela Mueller, "Employment Effects of Business Dynamics: Mice, Gazelles and Elephants," *Small Business Economics* 30 (2008): 85-100.

23. The numbers reported are the collective growth rates of all clustered and all isolated establishments. At the level of the individual establishment, the average annual compound growth rate was 4.2 percent versus 3.4 percent in favor of clustered establishments. This difference was statistically significant with a p-value of less than 0.01.

24. These low-exporting segments were as follows: waste management and treatment, recycling and reuse, remediation, training, waste-to-energy, conservation, hydropower, regulation and compliance, and public mass transit. It was deemed that clustering dynamics (or agglomeration economies in the technical jargon) are less relevant for these sectors because there is little private-sector competition and they are untraded. However, some of the advantages of clustering could still work to increase efficiency and productivity in these segments.

CHAPTER 5

1. See Bloomberg New Energy Finance, "Weathering the Storm: Public Financing for Low-Carbon Energy in the Post-Financial Crisis Era" (Washington, 2010) and DBCCA, "Investing in Climate Change 2011."

2. Bloomberg New Energy Finance data on U.S. and Chinese asset finance from 2004 to 2010 show that while financings have grown in both nations, China has far outpaced the U.S. in the last few years. Chinese asset financings increased from $1.5 billion in 2004 to $47.3 billion in 2010. By contrast, U.S. asset investment grew much more slowly, rising from $2.8 billion in 2004 to $21.9 billion in 2008 before slipping to $20.7 billion in 2010—a level less than half the Chinese amount.

3. Data through 2008. "Environmental Technologies Industries: FY2010 Industry Assessment" (Washington: International Trade Administration, 2010). U.S. Ron Senator Wyden's much-referenced reports on U.S. trade in environmental goods, which track a basket of 43 climate-friendly environmental technology products, confirm this broad trend through 2009. See "U.S. Trade in Environmental Goods: Updated Report to Major Opportunities and Challenges to U.S. Exports of Environmental Goods" (Washington: Office of Senator Ron Wyden, December 2010).

4. Google and Good Energies, an investment firm specializing in renewable energy, each agreed to take 37.5 percent of the equity portion of the transmission line project at a cost of $200 million each. Envision: Charlotte is a first-of-a-kind collaborative partnership among major employers, building owners and managers along with municipal and technology leaders to create the most environmentally sustainable urban core in the nation.

5. See, for example, Rebecca Henderson and Richard G. Newell, "Introduction and Summary," in Rebecca Henderson and Richard G. Newell, eds., *Accelerating Energy Innovation: Insights from Multiple Sectors*. (Cambridge: National Bureau of Economic Research, forthcoming). Available at www.nber.org/books/hend09-1/. This sort of argument has also been made by Richard Kauffman in "Has China Won the U.S. Solar War? *Huffington Post*, January 19, 2011. See also Richard Newell, "The Role of Markets and Policies in Delivering Innovation for Climate Change Mitigation," *Oxford Review of Economic Policy* 26 (2010): 253-269.

6. See, Michael Porter, *The Competitive Advantage of Nations* (New York: Free Press, 1990).

7. To be sure, narrow segments of the clean economy, such as energy-saving consumer products, green building materials, or solar photovoltaic, face very specific market making challenges and it is beyond the scope of this report to go into detail for each of those. The report attempts to highlight some high level, salient problems that impede the growth of the entire clean economy or significant chunks of it.

8. See, for example, Greenstone and Looney, "A Strategy for America's Energy Future."

9. See, for example, Newell, "The Role of Markets and Policies." See also, Carolyn Fischer and Richard Newell, "Environmental and Technology Policies for Climate Mitigation," *Journal of Environmental Economics and Management* 55 (2) (2008). And, Carolyn Fischer, "The Role of Technology Policies in Climate Mitigation." Issue Brief #09-08 (Washington: Resources for the Future, July 2009).

10. See Bloomberg New Energy Finance, "Crossing the Valley of Death" (New York, 2010) for a discussion on how governments, as first adopters, can play a direct role in fostering clean technologies.

11. Kate Manuel and L. Elaine Halchin, "Environmental Considerations in Federal Procurement: An Overview of the Legal Authorities and Their Implementation," CRS Report for Congress (June 2010). There is also the problem that environmental objectives compete with other policy objectives and interests such as obtaining high quality goods at low prices through competition, protecting American manufacturing from foreign competition, and ensuring opportunities for small businesses. See also Eric Fischer, "Green Procurement: Overview and Issues for Congress," (Washington: Congressional Research Service, April 2010).

12. See Blair Hamilton, "Developing Effective and Sustainable Financing Approaches." In *Scaling Up Building Energy Retrofitting in U.S. Cities* (Montpelier, VT: Institute for Sustainable Communities, June 2009). See also, Merrian Fuller, "Enabling Investments in Energy Efficiency: A Study of Programs that Eliminate First Cost Barriers for the Residential Sector" (Burlington, VT: Efficiency Vermont, August 2008). See Derek Suppie, "Financing Models for Energy Efficiency and Renewable Energy in Existing Models" (Milwaukee: Institute for Building Efficiency and Johnson Controls, September 2010). Johnson Controls and the international Facility Management association (IFMa) surveyed over 1400 executives with budget responsibility for their company's facilities during the spring of 2009. When asked what the top barrier for energy efficiency was, the most frequent response amongst managers, consistent across a wide variety of industries, was capital availability.

13. Deep energy retrofit packages can cost anywhere from $6,000 to $20,000 per home and require longer financing with terms of 10 to 20 years. Direct cash incentives such as rebates and grants do not completely cover the full upfront cost of clean energy investment. In this regard, many states, municipalities and utilities are continuing to offer traditional financing programs (e.g., revolving loan funds, energy savings performance contracting) and experiment with innovative financing mechanisms (e.g., utility on-bill financing, property assessed clean energy) that can operate in parallel with rebates and grants, lowering the cost of the project and shortening the payback period for financing. However, these financing programs have also not been widespread or designed to offer a large number of loans and come with their own specific challenges in design and implementation. For a review of various clean energy financing mechanisms, see Devashree Saha, Sue Gander, Greg Dierkers, "State Clean Energy Financing Guidebook" (Washington: National Governors Association Center for Best Practices, January 2011).

14. ARRA represents a one-time historic infusion of funds that is expected to be temporary. For instance, DOE funded the State Energy Program (SEP) at $25 million each in FY 2009 and FY 2010 in SEP formula funding, and ARRA provided $3.1 billion for SEO formula grants. For FY 2011, SEP received $50 million, with $39 million of that amount in formula funding and the rest in technical assistance support. DOE funded the Weatherization Assistance Program (WAP) at $250 million in FY 2009, and ARRA provided $5 billion. For FY 2011, WAP received $174.3 million. See www.naseo.org/news/releases/2011-05-20.pdf.

15. For an overview of the characteristics of the water and wastewater sector and the challenges it faces see Haarmeyer and Coy, "An Overview of Private Sector Participation."

16. See, for instance, Marilyn Brown and Sharon Chandler, "Governing Confusion: How Statutes, Fiscal Policy, and Regulations Impede Clean Energy Technologies," *Stanford Law and Policy Review* 472 (19) (2008). See also Benjamin Savacool and Chistopher Cooper, "Congress Got It Wrong: The Case for a National Renewable Portfolio Standard and Implications for Policy," *Environmental and Energy Law and Policy Journal* 85 (3) (2008); and Lincoln Davis, "Power Forward: The Argument for a National RPS," *Connecticut Law Review* 42 (5) (July 2010).

17. Richard Lester and David Hart, "The Great Unlocking: A Comprehensive Energy Innovation Strategy for the U.S." Discussion draft (Industrial Performance Center, Massachusetts Institute of Technology, 2011)

18. The Senate Committee on Energy and Natural Resources (ENR) released a Clean Energy Standard White Paper in March 2011 that lays out key questions and potential design elements of a CES. The white paper solicited inputs from stakeholders to inform the early consideration of a national CES by the ENR Committee. For more details, see www.energy.senate.gov/public/_files/CESWhitePaper.pdf. However, it does not seem likely that a "clean energy standard" is forthcoming anytime soon. See, for example, "Outlook Bleak for Passing CES, Repealing Oil Subsidies - Binqaman." *Greenwire*, May 16, 2011.

19. The Center for American Progress and the Coalition for Green Capital have advanced the concept of "races to the top" in the clean energy realm in Bracken Hendricks and others, "Cutting the Cost of Clean Energy 1.0" (Washington: Center for American Progress and the Coalition for Green Capital, 2011).

20. The greening of federal activities and the use of federal procurement to create stable market demand has been an object of bipartisan interest in both Congress and the executive, through both Republican and Democratic administrations. More recently, in response to Executive Order on Federal Leadership in Environmental, Energy, and Economic Performance (EO 13514) signed by President Obama in 2009, federal agencies have released Strategic Sustainability Performance Plans that outline how they will achieve the environmental, energy, and economic goals set forth in the executive order. This is the first time that federal agencies have developed and submitted detailed sustainability plans. See www.whitehouse.gov/administration/eop/ceq/sustainability/plans. For a discussion of how energy and environmental innovation has been driven by Department of Defense procurement through both the Bush and Obama administrations, see Matthew Hourihan and Matthew Stepp, "Lean, Mean, and Clean: Energy Innovation and the Department of Defense" (Washington: Information Technology and Innovation Foundation, 2011).

21. More ambitious reforms would make an even bigger difference. For instance, Congress should help strengthen FERC's authority to promote these reforms and make electricity markets more competitive by revising the Federal Power Act.

22. States have taken action in several policy areas that are driving the demand for clean energy investment. 36 states have renewable portfolio standards or goals and 24 states have energy efficiency resource standards or goals. 43 states have adopted a net metering policy and 41 states have adopted an interconnection policy. 21 states have public benefit funds (PBFs) supporting energy efficiency and 16 have PBFs for renewable energy. 11 states have adopted the most recent building energy codes or more stringent codes in the residential sector (IECC 2009); 15 have done so in the commercial sector (ASHRAE 90.1-2007). 47 states have one or more tax incentives supporting renewable energy; 24 states have one or more tax incentives directed at energy efficiency. For more information, see Rachel Escobar and Sue Gander, "Clean and Secure State Energy Actions - 2010 Update" (Washington: National Governors Association, August 2010). See also the Database of State Incentives for Renewables and Efficiency (DSIRE) Summary Maps, available at www.dsireusa.org/summarymaps/index.cfm.

23. As state RPS experience accumulates, studies have begun to evaluate RPS impact and effectiveness. See Langniss and Wiser, "The Renewable Portfolio Standard in Texas: An Early Assessment," *Energy Policy* 31 (6) (2003). This study reports positive initial results from the establishment of RPS in Texas. See also Carley, "State Renewable Energy Electricity Policies: An Empirical Evaluation of Effectiveness," *Energy Policy* 37 (8) (2009) and Powers and Yin, "Do State Renewable Portfolio Standards Promote In-State Renewable Generation?" *Energy Policy* 38 (5) (2010). Both studies credit RPS implementation with increasing total renewable energy generation across the nation. More recently, the implementation over time of RPS standards has been credited with significantly expanding installed wind capacity in both Colorado and Texas. Installed

wind capacity grew by a factor of five between 2004-2007 after Colorado's RPS came into effect in 2004, and similarly Texas witnessed a quintupling of installed capacity in the four years following the passage of its RPS in 2005. See Joshua Freed, Elizabeth Horwitz, and Nicholas Cunningham, "A Clean Energy Standard: Getting the United States Back Into the Clean Energy Race" (Washington: Third Way, March 2011).

24. Examples of states that have ratcheted up their electricity sourcing targets include Colorado, which has twice updated its RPS, and Nevada, which increased its RPS target in 2009. Resource eligibility has expanded beyond traditional renewable energy resources to cover energy efficiency and other supply-side technologies. For a more detailed discussion on state revisions of RPS, see Ryan Wiser and Galen Barbose, "Renewable Portfolio Standards in the United States: A Status Report with Data Through 2007" (Berkeley: Lawrence Berkeley National Laboratory, 2008). For background on state-by-state RPS coverage visit the Pew Center on Global Climate Change at www.pewclimate.org/what_s_being_done/in_the_states/rps.cfm.

25. States have been leveraging their procurement power to drive the clean economy revolution through advanced energy efficiency and renewable energy requirements for new and existing publicly funded buildings, facilities, and fleets; energy efficient and green product procurement (for instance, requiring all appliances and equipment purchases to meet the ENERGY STAR requirement); and using renewable energy either through generation at public facilities or on public lands, or by purchasing renewable energy directly from the electricity provider in what is popularly called green power purchasing. For more details on state best practices, see Maria Ellingson and Lesley Hunter, "Compendium of Best Practices: Sharing Local and State Successes in Energy Efficiency and Renewable Energy from the United States" (Renewable Energy and Energy Efficiency Partnership, Alliance to Save Energy, and American Council on Renewable Energy, May 2010). See also Alison Partin, "Greening State Government: 'Lead by Example' Initiatives" (Washington: National Governors Association, July 2008). For further details on how states can maximize their efforts by designing comprehensive programs, see U.S. Environmental Protection Agency, "Clean Energy Lead by Example Guide" (June 2009). Available at www.epa.gov/statelocalclimate/documents/pdf/epa_lbe_full.pdf. See also ACEEE, "How State Governments can Lead by Example" at www.aceee.org/files/pdf/fact-sheet/State%20Toolkit_Lead%20by%20Example.pdf.

26. See Saha and others, "State Clean Energy Financing Guidebook." The Department of Energy's Solution Center highlights nine particularly effective financing mechanisms: state and municipal revolving loan funds, third party loans, energy savings performance contracting, property-assessed clean energy, on-bill repayment, energy efficient mortgages, power purchase agreements, FHA Power Saver, and qualified energy conservation bond programs. See www1.eere.energy.gov/wip/solutioncenter/financialproducts/financingprograms.html.

27. American Wind Energy Association and Solar Energy Industry Association, "Green Power Superhighways Building a Path to America's Clean Energy Future" (2009); William W. Hogan, "Electricity Wholesale Market Design in a Low Carbon Future," in Jorge Padilla and Richard Schmalensee, eds., Harnessing Renewable Energy (Washington: Resources for the Future Press, 2010).

28. See, for instance, the IEA's report providing guidance to local policymakers to enhance the deployment and use of renewable energy resources within their geographic boundaries, International Energy Agency, "Cities, Towns and Renewable Energy: Yes in my Front Yard," (2009).

29. See the Playbook for Green Buildings available at www.greenplaybook.org/buildings/index.htm

30. For instance, the global C40 Cities Climate Leadership Group, chaired by New York City Mayor Bloomberg, recently released its flagship report in which 36 global cities—including Austin, Chicago, Los Angeles, New Orleans, New York, Philadelphia, Portland, Seattle, and San Francisco—disclose their carbon emissions. The report will inform cities' emissions-reduction efforts and establish a benchmark for judging the effectiveness of present and future policies. KPMG Advisory N.V., "CDP Cities 2011: Global Report on C40 Cities," report prepared for C40 Cities Climate Leadership Group (2011).

31. See, for example, BNEF, "Crossing the Valley of Death."

32. Ibid.

33. Clear analyses of the "commercialization Valley of Death" can be found in BNEF's "Crossing the Valley of Death" and Eliot Jamison, "From Innovation to Infrastructure: Financing First Commercial Clean Energy Projects" (San Francisco: CalCEF, 2010).

34. The Solar Energy Industries Association, for one, has complained about long processing delays associated with the Loan Guarantee Program's multi-agency review process as well as recent budget-related "holds" on pending applications. See Solar Energy Industries Association, www.seia.org/galleries/FactSheets/Factsheet_DOE_LGP.pdf as well as www.seia.org/galleries/pdf/SEIA_Letter_to_Congressional_Leaders_on_LGP_5.11.11.pdf.

35. Jamison, "From Innovation to Infrastructure." See also Jenny Mandel, "Loan Guarantee Program's Financial Rigor Slows It Down," *E&E News*, April 1, 2011.

36. For a good discussion of these and other flaws in the structure and nature of renewable energy subsidies see Nate Gorence and Sasha Mackler, "Reassessing Renewable Energy Subsidies" (Washington: Bipartisan Policy Center, 2011).

37. Originally enacted in 1992, the PTC has been renewed and expanded numerous times, most recently through the Energy Improvement and Extension Act of 2008 and the American Recovery and Reinvestment Act (ARRA) of 2009. Through ARRA, Congress acted to provide a three-year extension of the PTC through December 31, 2012. Wind projects must be in place before January 1, 2013 and other projects in general before January 1, 2014. For more details, see American Wind Energy Association, "What is the Current Status of the Production Tax Credit." Available at www.americanwindenergyassociation.net/ei_policy_ptc.cfm. The ITC similarly has gone through several revisions, most notably through the Energy Improvement and Extension Act of 2008 and subsequently under ARRA. Through ARRA, qualifying wind projects can, for a limited time, choose between a 30 percent ITC or a 30 percent cash grant in lieu of the PTC.

38. For background on CEDA, see Senate Committee on Energy & Natural Resources, "The 21st Century Energy Technology Deployment Act" (April 2009). Available at www.energy.senate.gov/public/_files/CEDAOnePageSummary.pdf. For more recent arguments in support of CEDA see the testimonies of Dan Reicher, Christopher Guith, and Kassia Yanosek before the Senate Energy & Natural Resources Committee on May 3, 2011. Available at www.energy.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_ID=929b04b3-bbb7-c4d3-c14a-e477af7b1291. For discussion of the so-called Energy Independence Trust model see Hendricks and others, "Cutting the Cost of Clean Energy I.D." For discussions of capital repatriation schemes as sources of investment finance see Reed Hundt and Thomas Mann, "Rebuild American Infrastructure? Companies' Offshore Profits Can Help," *Washington Post*, June 16, 2011 and Elise Zoli and Peter Rothstein, "Repatriation to Accelerate Clean Energy (RACE): New Private Capital for Cleantech Investment and Deployment on a Pilot Scale." Presentation, April 22, 2011.

39. For discussions of the need to restructure renewable energy investment incentives see Steven Hayward and others, "Post-Partisan Power" (Oakland: The Breakthrough Institute, 2010) and Gorence and Mackler, "Reassessing Renewable Energy Subsidies," which provides a rich discussion of the problems, potential solutions, and the political moment.

40. Gorence and Mackler, "Reassessing Renewable Energy Subsidies" provides a detailed discussion of reverse auctions.

41. For information on Connecticut's programs see the CDA's technology oriented expansion finance programs see www.ctcda.com/Financing/Specialty_Programs/TECHNOLOGY_INTENSIVE. For more information on the California alternative vehicle program see the California Energy Commission website at www.energy.ca.gov/altfuels/index.html.

42. This concept is described in Jamison, "From Innovation to Infrastructure."

43. See BNEF, "Crossing the Valley of Death."

44. On the general importance of innovation to economic growth see Robert Atkinson and Howard Wial, "Boosting Innovation, Productivity, and Growth Through a National Innovation Foundation" (Washington: Brookings Institution, 2008). See also, on the energy field, and Richard Newell, "A U.S. Innovation Strategy for Climate Change Mitigation" (Washington: Brookings Institution / Hamilton Project, 2008). James Duderstadt and others, "Energy Discovery-Innovation Institutes: A Step Towards America's Energy Future" (Washington: Brookings Institution, 2009); and Hayward and others, "Post Partisan Power," and Hourihan and Atkinson, "Inducing Innovation."

45. See, among many others, Duderstadt and others, "Energy Discovery-Innovation Institutes" and Hayward and others, "Post Partisan Power." In the energy field, the "levelized" costs of new renewable electricity technologies remain substantially higher than conventional coal and natural gas-fired fossil power plants, according to the U.S. Energy Information Administration. For plants entering service in 2016, these estimates suggest that while the costs of conventional coal-fired plants going online in 2016 would come in at about $95 per megawatt hour (MWh), those for onshore wind generation clock in at $97, for geothermal at $101, and for advanced nuclear at $113. Solar PV generation will run to $211, offshore wind $243, and solar thermal to $312. See U.S. Department of Energy, "2016 Levelized Cost of New Generation Resources from the Annual Energy Outlook 2010" (Energy Information Administration). Available at www.eia.doe.gov/oiaf/aeo/electricity_generation.html. The International Energy Agency similarly writes that "a global revolution is needed in the ways that energy is supplied and used" and outlines detailed roadmaps for both the incremental and dramatic innovations necessary to enable "all countries to put in motion a transition to a more secure, lower-carbon energy [system], without undermining economic growth." International Energy Agency, "Energy Technology Perspectives 2008" (Paris, 2011).

46. For an early review of the literature see David Mowery and Nathan Rosenberg, "The Influence of Market Demand upon Innovation: A Critical Review of Some Recent Empirical Studies," *Research Policy* 8 (2) (1979). More recent treatments of the interplay of "induced" and "pushed" innovation include: Adam Jaffe, Richard Newell, and Robert Stavins, "Environmental Policy and Technological Change," *Environmental and Resource Economics* 22 (1-2) (2002); Adam Jaffe, Richard Newell, and Robert Stavins, "A Tale of Two Market Failures: Technology and Environmental Policy," *Ecological Economics* 54 (2005): 164-174; Gregory Nemet, "Demand-Pull, Technology-Push, and Government-Led Incentives for Non-Incremental Technical Change," *Research Policy* 38 (2009): 700-709; and David Popp, Richard Newell, and Adam Jaffe, "Energy, the Environment, and Technological Change," Working Paper. (Cambridge: National Bureau of Economic Research, 2009). See also Duderstadt and others, "Energy Discovery-Innovation Institutes;" Hayward and others, "Post Partisan Power;" and Matt Hourihan and Robert

Atkinson, "Inducing Innovation: What a Carbon Price Can and Can't Do" (Washington: Information Technology and Innovation Foundation, 2011).

47. Among the numerous market failures and barriers that prevent private firms from adequately investing in the development of new, high-risk energy and environmental technologies and business models are: the high relative price of new technologies; knowledge spillover risks; uncertainty about the present and future regulatory environment and prices; the heavy requirements of new infrastructure required by many new energy technologies; and the scale and long time-horizon of many projects. See Marilyn Brown, "Market Failures and Barriers as A Basis for Clean Energy Policies," *Energy Policy* 29 (2001): 1197-1207; Jaffe and others., "A Tale of Two Market Failures;" Atkinson and Wial, "Boosting Productivity;" and Duderstadt and others, "Energy Discovery-Innovation Institutes."

48. See, for example, Newell, "A U.S. Innovation Strategy for Climate Change Mitigation" and Duderstadt and others, "Energy Discovery-Innovation Institutes." See also American Energy Innovation Council, "A Business Plan for America's Energy Future" (Washington, 2010); President's Council of Advisors on Science and Technology, "Report to the President on Accelerating the Pace of Change in Energy Technologies Through an Integrated Federal Energy Policy" (The White House, November 2010); and Heyward and others, "Post Partisan Power."

49. K.S. Gallagher and L. D. Anadon, "DOE Budget Authority for Energy Research, Development, and Demonstration Database," Energy Technology Innovation Policy, John F. Kennedy School of Government, Harvard University, March 3, 2011. Figures reported are the sum total of the "Total Energy Technology RD&D" and "Basic Energy Sciences" budgets in 2005 dollars. The assessment here includes Basic Energy Sciences (BES) (while others do not) because BES funds some of the Department of Energy's most innovative programs beyond ARPA-E (like the Energy-Regional Innovation Clusters (E-RIC) and Energy Frontier Research Centers (EFRCs), in addition to energy-related fundamental research at institutions across the country. Other transparent and similarly legitimate tabulations choose to exclude BES and arrive at lower estimates of energy R&D accordingly. The Energy Innovation Tracker at http://energyinnovation.us/ is a particularly good resource. It should be noted too that the Recovery Act has already pumped over $22 billion into the third and growing "D:" deployment.

50. See Duderstadt and others, "Energy Discovery-Innovation Institutes" and American Energy Innovation Council, "A Business Plan for America's Energy Future." See also Mark Muro and Sarah Rahman, "$15 billion: The New Energy Target." The Avenue, a blog of *The New Republic*, November 2, 2009.

51. Organization for Economic Cooperation and Development iLibrary, "Government Budget Appropriations or Outlays for R&D by Socioeconomic Objective," accessed May 11, 2011 and available at www.oecd-ilibrary.org/statistics. Includes federal energy research and development (and excludes demonstration) spending as reported by member countries to the OECD. International comparison only available through 2009.

52. The National Center for Science and the Environment's "Handbook of Federal Funding for Environmental R&D - FY 2011" tallies $9.1 billion in total federal environmental R&D funding in 2010 spread across 11 agencies–a considerable number. The largest sponsor of environment-related R&D is the Department of Energy, whose efforts encompass mainly renewable energy and energy efficiency projects meant to reduce the environmental impact of energy production and consumption, which have been growing swiftly since 2006 but we categorize as energy R&D. Much of the R&D conducted by other significant sponsors like NASA, NOAA, and NSF we consider basic research rather than applied R&D. The subtle distinction here is between invaluable basic research into *how the climate is changing* from NASA and NOAA, and more market-oriented applied research into and development of *technologies that can mitigate change*, for example. This report's focus on the production of goods and services with an environmental purpose aligns closest with EPA's R&D portfolio, though surely spillover benefits accrue from the Department of Defense's efforts to reduce its environmental impact and the Department of Agriculture's water management innovations, for example, as well.

53. Organization for Economic Cooperation and Development iLibrary, "Government Budget Appropriations or Outlays for R&D by Socioeconomic Objective," accessed May 11, 2011 and available at www.oecd-ilibrary.org/statistics. Includes research and development spending with an environmental objective, as reported by countries to the OECD. International comparisons only available through 2009.

54. See Dan Kammen, "The Case for State RD&D Programs," presentation made at the National Governors Association State Workshop on Clean Energy Research, Development, and Demonstration (March 2008).

55. See Jim Duderstadt and others, "Energy Discovery-Innovation Institutes."

56. In August 2009, the DOE established 46 Energy Frontier Research Centers comprising universities, national laboratories, non-profit organizations, and for-profit firms. These Centers were funded at $2-5 million per year for a 5-year initial award period. For more information, see DOE's Energy Frontier Research Centers website at www.er.doe.gov/bes/EFRC/index.html. Modeled after the Department of Defense's Defense Advanced Research Projects Agency (DARPA), the DOE's ARPA-E program was created by H.R. 364 in 2007 but only allocated a budget of $400 million in April 2009 through ARRA. Like DARPA, ARPA-E identifies game changing ideas and funds them. At least six ARPA-E projects, ranging from solar and wind to advanced batteries have gone on to win additional backing from venture capitalists. For more details, see www.arpa-e.energy.gov/. In FY 2010 budget, DOE requested financing for Energy Innovation Hubs in eight areas: smart grid, solar electricity, carbon capture and storage, extreme materials, batteries and energy storage, energy efficiency buildings, nuclear energy, and fuels from sunlight. Thus far, three hubs have been launched: the Energy-Efficient Buildings System Design Hub run by the Greater Philadelphia Innovation Cluster (GPIC), led by Penn State University; the Fuels from Sunlight Energy Innovation Hub run by the Joint Center for Artificial Photosynthesis, led by Caltech; and the Nuclear Energy Modeling and Simulation Energy Innovation Hub run by the Oak Ridge National Laboratory. For details, see www.energy.gov/hubs/index.htm.

57. For general information on the WITC, visit www.epa.gov/witc/index.html. See also "Administrator Jackson, SBA Administrator Mills Announce launch of Water Technology Innovation Cluster" (U.S. Environmental Protection Agency Press Release, January 18, 2011).

58. See www.eesi.org/fy-2011-budget-compromise-cuts-funding-environmental-energy-programs-19-apr-2011.

59. The Obama administration's FY 2012 budget request includes $100 million to continue supporting the 46 Energy Frontier Research Centers; $550 million for ARPA-E; and $146 million to support the three existing Energy Innovation Hubs and to establish three new Hubs in the areas of batteries and energy storage, smart grid technologies and systems, and critical materials. See www.energy.gov/news/10064.htm.

60. For information on the Clean Energy Innovation Consortia proposal see www.energyinnovationconsortia.org/.

61. For the concept of a Water Innovation Center, see G. Allen Burton and others, "Leveraging the Great Lakes Region's Water Assets for Economic Growth" (Washington: Brookings Institution, 2010).

62. For discussion of these and other revenue ideas see Hayward and others, "Post Partisan Power" and the President's Council of Advisors on Science and Technology, "Report to the President on Accelerating the Pace of Change in Energy Technologies Through an Integrated Federal Energy Policy" (Washington: 2010). See also Hundt and Mann, "Rebuild American Infrastructure?" and Zoli and Rothstein, "Repatriation to Accelerate Clean Energy."

63. For background on state efforts in clean energy RD&D, see Daniel Kammen, "Opportunities for States in Clean Energy Research, Development & Demonstration," (National Governors Association, 2008). This report identified nine states as having dedicated clean energy RD&D funds: California, Connecticut, Florida, Illinois, Massachusetts, Minnesota, New Jersey, New York, and Wisconsin. See also Escobar and Gander, "Clean and Secure State Energy Actions," which lists state-by-state actions on clean energy RD&D between July 2008 and May 2010. State efforts in clean energy RD&D can be broadly categorized under direct investment in research; supporting incubators; establishing seed funds to bridge funding gap between lab research and venture funding; and supporting demonstration projects. States' direct investment in research is mostly achieved through the creation and funding of research centers within state universities. Examples include the Florida Solar Energy Research Center, Oregon's Built Environment & Sustainable Technologies Center (BEST), South Dakota's 2010 Research Centers, and Virginia's Coastal Energy Research Consortium (VCERC). States also provide support to cleantech incubators that provide guidance, technical assistance, and consultation to companies to help them develop and commercialize clean technologies. Examples of this include the Colorado Collaboratory and NYSERDA's Clean Energy Business Incubator program. Moving along the cleantech RD&D continuum, states also provide seed funds to help companies develop and commercialize their products and services. Some state examples are: Iowa Power Fund supporting research, development, commercialization, and deployment of biofuels, renewable energy technologies, and energy efficiency technologies; MassCEC's investments in the Advancement of Technology program that makes venture capital equity investments in promising early-stage clean energy companies that are developing and commercializing technologies; and the Edison Innovation Clean Energy Fund that helps New Jersey companies in demonstration projects and developmental and ancillary activities necessary to commercialize energy efficiency and renewable energy technologies. Typical state awards in this category can range anywhere from $100,000 up to $500,000. Finally, some states can maintain dedicated grants and awards supporting demonstration projects. These include the Connecticut Clean Energy Fund's Operational Demonstration Program; the Delaware Green Energy Fund's Technology and Demonstration Program; Massachusetts' Catalyst Program; and South Carolina's Renewable Energy Grant program, which provides matching grants for demonstration projects. Awards for demonstration projects can range from $40,000, as in the Massachusetts example, to $500,000, as in the Connecticut example.

64. For background on the state clean energy funds, see Lewis Milford and others, "Clean Energy and Economic Development: How Existing and New State Clean Energy Funds Could Become the Engines of Job Growth, Industry Creation, and Exports" (Washington: Brookings Institution, forthcoming).

65. Deutsche Bank Climate Change Advisors, in a similar discussion, argues that "`TLC'=transparency, longevity, and certainty-drives investment." They say: "Investors need transparency in policies to create understanding and a level playing field. Longevity means policy has to match the timeframe of the investment and stay the course. Certainty refers to knowing that incentives are financeable and can be trusted in the financial return calculation and again are likely to be maintained over the course of the investment. TLC should result in a lower cost of capital for projects while still delivering a fair and market-related return to capital." See DBCCA, "Investing in Climate Change 2011."

66. They do this by facilitating dense knowledge flows, the sharing of vital resources, and the matching of specialized workers to firms. In one influential discussion, the urban economist Gilles Duranton has identified three mechanisms by which clusters work: learning, sharing, and matching. Learning is facilitated in clusters as workers share knowledge with one another, switch firms, or create start-ups after leaving an older firm. Clustered firms share a number of potentially vital resources like specialized suppliers or clients, organizations (e.g. university departments, research organizations, grant-making foundations), infrastructure (e.g. roads, ports, and even office buildings), labor, training programs, and a favorable policy environment. Finally, in a clustered environment, it is easier for workers to match their specialized skills with the right firm or vice versa. See Gilles Duranton, Philippe Martin, Thierry Mayer, and Florian Mayneris, *The Economics of Clusters: Evidence from France* (Oxford: Oxford University Press, 2010).

67. For more extensive discussion of the significance of regional industry clusters see, among other literature, Mark Muro and Bruce Katz, "The New 'Cluster Moment:' How Regional Innovation Clusters Can Foster the Next Economy" (Washington: Brookings Institution, 2010).

68. For a discussion of the nature and economic importance of regional industry clusters see Muro and Katz, "The New 'Cluster Moment.'"

69. For a review of recent federal cluster offerings see Muro and Katz, "The New 'Cluster Moment.'" Note that "clean" and "green" initiatives have figured among the winners of several of these initial offerings. Three of the 10 "Innovation Economies" that received SBA Regional Cluster Initiative pilot grants last fall involved clean industries. These ranged from the Carolinas' nuclear cluster to Connecticut's hydrogen fuel cell coalition and the Illinois Smart Grid cluster. Likewise, the Oregon Built Environment and Sustainable Technologies Center is a partner in one of the six consortia that won EDA's i6 Challenge.

70. For information on the Energy Regional Innovation Cluster for efficient buildings systems, see www.energy.gov/hubs/eric.htm. For information on the i6 Green Challenge, see www.energy.gov/news/10169.htm.

71. For information on various cluster- or region-focused state clean economy development initiatives, see the following websites: Colorado: www.coloradocollaboratory.org/; New York: www.nyserda.org/publications/2010_Strategic_Plan.pdf; Oregon: www.oregonbusinessplan.org/Industry-Clusters/About-Oregons-Industry-Clusters.aspx.

72. In FY 2010 the EDA, SBA, and USDA made available less than $150 million in small grants for regional innovation clusters programming. In that year, the EDA received 83 applications for grants under the i6 Challenge and made six awards. This spring, the agency had by early May received 140 letters of intent to apply for the i6 Green Challenge, which will also make just six awards. Correspondence with John Fernandez, EDA administrator, April 29, 2011 and May 2, 2011.

73. Duderstadt and others, "Energy Discovery-Innovation Institutes."

74. For a view of these matters across multiple sectors see Mark Muro and Kenan Fikri, "Job Creation on a Budget: How Regional Industry Clusters Can Add Jobs, Bolster Entrepreneurship, and Spark Innovation" (Washington: Brookings Institution, 2011).

75. One-third of the current 400,000 jobs in the electric power industry will become vacant by 2013, following a wave of baby boomer retirements, and will need to be replaced with well-trained workers skilled in various clean energy technology operation. See the National Commission on Energy Policy, "Task Force on America's Future Energy Jobs" (Washington: October 2009). A Lawrence Berkeley National Laboratory report projects a two- to four-fold increase in the size of the energy efficiency sector between 2008-2020, with workforce need reaching a 220,000 person-year equivalent (PYE) in a low growth scenario to a 380,000 PYE in a high growth scenario in 2020. See Charles Goldman, Jane Peters, Nathaniel Alters, Elizabeth Stuart, and Merrian Fuller, "Energy Efficiency Services Sector: Workforce Education and Training Needs" (Berkeley Lawrence Berkeley National Laboratory, 2010). The American Solar Energy Society estimates that renewable energy and energy efficiency sectors combined would grow from 9 million in 2007 to 16.3 million jobs by 2030, assuming no new federal-level clean energy policy initiatives. See Roger Bezdek, "Green Collar Jobs in the U.S. and Colorado: Economic Drivers for the 21st Century" (Boulder: American Solar Energy Society, 2008).

76. See Michael Fletcher, "Retrained for Green Jobs, but still waiting on work." *The Washington Post*, November 22, 2010. See also, Abby Gruen, "N.J Green Jobs Creation Slow, Despite Grants." *The Newark Star Ledger*, April 7, 2010. According to a recent state-backed University of California, Berkeley report, California's job market in the energy efficiency sector will remain tight through 2020 and, rather than funding training programs for new workers, the focus should be on upgrading the energy efficiency skills and knowledge of the incumbent workforce. See Carol Zabin and others., "California Workforce Education & Training Needs Assessment" (Donald Vial Center on Employment in the Green Economy, University of California, Berkeley, 2011). The concerns about "too many workers, too few jobs" seem especially troublesome in the backdrop of significant infusion of ARRA dollars for purpose of job training and preparing workers for careers in clean economy. Through ARRA, the Department of Labor has allotted $500 million, across five categories, for clean energy workforce training. The Department of Energy has provided up to $100 million for smart grid workforce training. In addition, many states are also using portions of their State Energy Program and Weatherization Assistance Program funding for clean energy workforce training. For more details, see Devashree Saha, "Enhancing State Clean Energy Workforce Training to Meet Demand" (Washington: National Governor's Association Center for Best Practices, 2010).

77. See, for example, National Commission on Energy Policy, "Task Force on America's Future Energy Jobs" and Saha, "Enhancing State Clean Energy Workforce Training to Meet Demand."

78. For background on the "regional innovation program' included in the AmericaCOMPETES reauthorization act last year, see Mark Muro, "AmericaCOMPETES: Pass It, Nevertheless," The Avenue, a blog of *The New Republic*, December 21, 2010.

79. For broader discussions of the regional or metropolitan focus of the U.S. economy, see Bruce Katz, Jennifer Bradley, and Amy Liu, "Delivering the Next Economy: The States Step Up" (Washington: Brookings Institution, 2010) and Bruce Katz and Jennifer Bradley, "Metro Connection." Democracy 20, Spring 2011.

80. For more comprehensive discussions of federal, state, and regional cluster dynamics and policy see Muro and Katz, "The New 'Cluster Moment,'" and Muro and Fikri, "Job Creation on Budget."

81. Muro and Fikri, "Job Creation on Budget" outlines one possible design for a competitive state cluster grant program.

82. All of the discussion of the regional analysis and coordination agenda draws heavily on Muro and Katz, "The New 'Cluster Moment.'"

83. Puget Sound Regional Council and Brookings Institution, "Innovation Meets Demonstration: A Prospectus for Catalyzing Growth in Puget Sound's Energy Efficiency Technology Cluster" (Washington, 2011).

84. See the Climate Prosperity Project, Inc. at www.climateprosperityproject.org/pilot_regions.htm.

85. Depending on the region, clean economy development activities may be facilitated or led by entities as varied as a regional economic development entity, a metropolitan planning organization, a university or consortia of universities, a formal cluster organization, or trade association.

86. For an overview of Climate Prosperity's activities in the four metro regions, see www.climateprosperityproject.org/.

87. For an overview of Syracuse Tech Garden's activities, see www.thetechgarden.com/cleantech.

88. For an overview of Milwaukee Water Council's activities, see www.thewatercouncil.com/.

89. For an overview of CleanTECH San Diego's activities, see www.cleantechsandiego.org/.

90. See, for instance, Zabin and others., "California Workforce Education & Training Needs Assessment."

91. See the Institute for Sustainable Communities' Case Study on "Los Angeles Trade-Technical College: A Model of Workforce Development in the Energy/Utility Sector" (May 2010). In a more rural setting the Renewable Energy Technology Program at Columbia Gorge Community College in Oregon emerged out of a dialogue with the private sector after wind manufacturers began opening wind farms in the region and seeking trained workers. For more details see SEED Center, "Columbia Gorge Community College Leads Nation in Wind Training," available at www.theseedcenter.org/Colleges-in-Action/Success-Stories/Columbia-Gorge-Community-College-Leads-Nation-in-W.

92. See the Institute for Sustainable Communities' Case Study on "Going to the Source: Seattle Turns to Employers on Green Job Potential and Job Training" (April 2010).

SELECTED REFERENCES

GENERAL

Accenture and Barclays. 2011. "Carbon Capital: Financing the Low Carbon Economy." London.

American Council on Renewable Energy. 2010. "U.S. Renewable Energy Quarterly Report." Washington.

Antholis, William, and Strobe Talbott. 2010. *Fast Forward: Ethics and Politics in the Age of Global Warming.* Washington: Brookings Institution Press.

Atkinson, Robert, and Darrene Hackler. 2010. "Economic Doctrines and Approaches to Climate Change." Washington: The Information Technology and Innovation Foundation.

Collaborative Economics. 2007. "California Green Innovation Index 2008." Palo Alto: Next 10.

--. 2009a. "California Green Innovation Index 2009. Palo Alto: Next 10.

--.2009b. "Many Shades of Green: Diversity and Distribution of California's Green Jobs." Palo Alto: Next 10.

Brown, Marilyn A., Frank Southworth, and Andrea Sarzynski. 2008. "Shrinking the Carbon Footprint of Metropolitan America." Washington: Brookings Institution.

Chapple, Karen, and others. 2010. "Innovating the Green Economy in California Regions." Berkeley: Institute of Urban and Regional Development.

Department for Business Innovation & Skills. 2009. "Towards a Low Carbon Economy - Economic Analysis and Evidence for a Low Carbon Industrial Strategy." BIS Economics Paper 1.

Deutsche Bank Climate Change Advisors. 2010. "Investing in Climate Change 2010: A Strategic Asset Allocation Perspective." Frankfurt am Main.

--. 2010. "Natural Gas and Renewables: A Secure Low Carbon Future Energy Plan for the United States." Frankfurt am Main.

--. 2011. "Investing in Climate Change 2011: The Mega-Trend Continues—Exploring Risk and Return." Frankfurt am Main.

Furman, Jason, and others. 2007. "An Economic Strategy to Address Climate Change and Promote Energy Security." Washington: Brookings Institution / The Hamilton Project.

Hall, Bronwyn H., and Josh Lerner. 2009. "The Financing of R&D and Innovation." Working Paper 15325. National Bureau of Economic Research.

Henderson, Rebecca, and Richard G. Newell, eds. 2010. *Accelerating Energy Innovation: Insights from Multiple Sectors.* National Bureau of Economic Research.

Innovas Group. 2009. "Low Carbon and Environmental Goods and Services: An Industry Analysis." London: U.K. Department for Business Enterprise and Regulatory Reform.

Jaffe, Adam B., and Robert N. Stavins. 1994. "The Energy-Efficiency Gap: What Does it Mean?" *Energy Policy* 22 (10): 804-810.

National Research Council. 2011. "America's Climate Choices." Washington: National Academies Press.

Newell, Richard G. 2010. "The Role of Markets and Policies in Delivering Innovation for Climate Change Mitigation." *Oxford Review of Economic Policy* 26: 253-269.

Pew Charitable Trusts. 2009. "The Clean Energy Economy: Repowering Jobs, Businesses and Investments Across America." Washington.

--. 2011. "Who's Winning the Clean Energy Race? 2010 Edition: G20 Investment Powering Forward." Washington.

Popp, David, Richard Newell, and Adam Jaffe. 2009. "Energy, the Environment, and Technological Change." Working Paper 14832. National Bureau of Economic Research.

Porter, Michael. 1990. *The Competitive Advantage of Nations.* New York: Free Press.

REN21: Renewable Energy Policy Network for the 21st Century. 2010. "Renewables 2010 Global Status Report." Paris.

Roberts, Michael J., Joseph B. Lassiter, and Ramana Nanda. "U.S. Department of Energy & Recovery Act Funding: Bridging the "Valley of Death." Harvard Business School Case 810-144.

Sinclair-Desgagné-Bernard. 2008. "The Environmental Goods and Services Industry." HEC Montréal, CIRANO, CIRAIG.

World Economic Forum. 2009. "Green Investing: Towards a Clean Energy Infrastructure." Geneva.

Worldwatch Institute. 2008. "Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World." Washington.

United Nations Environment Program. 2007. "Global Environmental Outlook 4." New York.

DEFINITIONS AND METHODS

Becker, Randy A., and Ronald J. Shadbegian. 2009. "Environmental Products Manufacturing: A Look Inside the Green Industry." *B.E. Journal of Economic Analysis & Policy* 9 (4).

European Communities. 2009. "The Environmental Goods and Services Sector: A Data Collection Handbook." Luxembourg.

Neumark, David, Junfu Zhang, and Brandon Wall. 2005. "Employment Dynamics and Business Relocation: New Evidence from the National Establishment Time Series." San Francisco: Public Policy Institute of California.

Organisation for Economic Co-Operation and Development. 1999. "The Environmental Goods & Services Industry: Manual for Data Collection and Analysis." Paris.

Pew Charitable Trusts. 2009. "The Clean Energy Economy: Repowering Jobs, Businesses and Investments Across America." Washington.

U.S. Department of Commerce Economics and Statistics Administration. 2010. "Measuring the Green Economy." Washington.

U.S. Department of Labor Bureau of Labor Statistics. 2010. "Notice of Solicitation of Comments." *Federal Register* 75 (50): 12571-12573.

U.S. Environmental Protection Agency. 1998. "Survey of Environmental Products and Services." Washington.

POLICY

Alic, John, and others. 2010. "A New Strategy for Energy Innovation." *Nature* 465: pp. 316-317.

American Energy Innovation Council. 2010. "A Business Plan for America's Energy Future."

Andes, Scott. 2010. "Buying Innovation: How Public Procurement Can Spur Innovation." Washington: The Information Technology & Innovation Foundation.

Atkinson, Robert, and others. 2009. "Rising Tigers, Sleeping Giant: Asian Nations Set to Dominate the Clean Energy Race by Out-Investing the United States." Oakland and Washington: Breakthrough Institute and Information Technology and Innovation Foundation.

Bipartisan Policy Center. 2010. "Clean Energy Technology Pathways: An Assessment of the Critical Barriers to Achieve a Low-Carbon Energy Future." Washington: Bipartisan Policy Center.

--. 2011. "Reassessing Renewable Energy Subsidies." Washington: Bipartisan Policy Center.

Bloomberg New Energy Finance. 2010. "Crossing the Valley of Death: Solutions to the Next Generation Clean Energy Project Financing Gap." New York.

--. 2010. "Weathering the Storm: Public Funding for low-carbon Energy in the Post-Financial Crisis Era."

Brown, Marilyn A., and Sharon Chandler. 2008. "Governing Confusion: How Statutes, Fiscal Policy, and Regulations Impede Clean Energy Technologies." *Stanford Law and Policy Review* 19 (3): 472-509.

Coleman, Will. 2011. Testimony before the Senate Energy and Natural Resources Committee. March 17.

Davies, Lincoln. 2010. "Power Forward: The Argument for a National RPS." *Connecticut Law Review* 42 (5): 1339-1403.

Department for Business, Innovation, and Skills and Department for Energy and Climate Change. 2009. "The U.K. Low Carbon Industrial Strategy." London.

Duderstadt, James J., Mark Muro, and Sarah Rahman. 2010. "Hubs of Transformation: Leveraging the Great Lakes Research Complex for Energy Innovation." Washington: Brookings.

Ellingson, Maria, and others. 2010. "Compendium of Best Practices: Sharing Local and State Successes in Energy Efficiency and Renewable Energy from the United States." Washington: Alliance to Save Energy, American Council on Renewable Energy, and Renewable Energy and Energy Efficiency Partnership.

Ghosh, Shikhar, and Ramana Nanda. 2010. "Venture Capital Investment in the Clean Energy Sector." Working paper 11-020. Harvard Business School.

Zindler, Ethan. 2011. "Clean Energy Investment Trends and the Impact of U.S. Domestic Policy." Testimony before the Senate Energy and Natural Resources Committee. Washington. March 17.

Greenstone, Michael and Adam Looney. 2011. "A Strategy for America's Energy Future: Illuminating Energy's Full Costs." Washington: Brookings Institution / The Hamilton Project.

Hayward, Steven F., and others. 2010. "Post-Partisan Power: How a Limited and Direct Approach to Energy Innovation Can Deliver Clean, Cheap Energy, Economic Productivity and National Prosperity." Oakland: Breakthrough Institute.

Hendricks, Bracken, and others. 2010. "Cutting the Cost of Clean Energy 1.0: Toward a Clean Energy Deployment Plan for Jobs, Security, and Broad-Based Economic Growth in 2011." Washington: Center for American Progress and Coalition for Green Capital.

Hendricks, Bracken, Sean Pool, and Lisbeth Kaufman. 2011. "Low-Carbon Innovation: A Uniquely American Strategy for Industrial Renewal." Washington: Center for American Progress.

Hourihan, Matt, and Matthew Stepp. 2011. "Lean, Mean and Clean: Energy Innovation and the Department of Defense." Washington: Information Technology and Innovation Foundation.

Hourihan, Matt, and Robert Atkinson. 2011. "Inducing Innovation: What a Carbon Price Can and Can't Do." Washington: Information Technology and Innovation Foundation.

Jaffe, Adam B., and others. 1995. "Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?" *Journal of Economic Literature* 33 (1): 132-163.

Jaffe, Adam B., Richard G. Newell, and Robert N. Stavins. 2002. "Environmental Policy and Technological Change." *Environmental and Resource Economics* 22: 41-69.

--. 2005. "A Tale of Two Market Failures: Technology and Environmental Policy." *Ecological Economics* 54: 164-174.

Kammen, Daniel. 2008. "Opportunities for States in Clean Energy Research, Development & Demonstration." Washington: National Governors Association.

Kauffman, Richard. 2011. "Has China Won the U.S. Solar War?" *Huffington Post.*

Milford, Lewis, and others. 2010. "Clean Energy Federalism: States Lead, Washington Follows–The Data Behind the Story." Working Paper. Montpelier: Clean Energy Group.

--. 2010. "Federal Climate and Energy Legislation and the States: Legislative Principles and Recommendations for a New Clean Energy Federalism." Montpelier: Clean Energy Group.

Milford, Lewis, and Jessica Morey. 2010. "Innovation to Infrastructure: Clean Energy without Cap and Trade." Montpelier: Clean Energy Group.

Mills, Karen G., Elisabeth B. Reynolds, and Andrew Reamer. 2008. "Clusters and Competitiveness: A New Federal Role for Stimulating Regional Economies." Washington: Brookings Institution.

Muro, Mark, and Kenan Fikri. 2011. "Job Creation on a Budget: How Regional Industry Clusters Can Add Jobs, Bolster Entrepreneurship, and Spark Innovation." Washington: Brookings Institution.

Muro, Mark, and Bruce Katz. 2010. "The New 'Cluster Moment:' How Regional Innovation Clusters Can Foster the Next Economy." Washington: Brookings Institution.

Muro, Mark, and Sarah Rahman. 2008. "Clusters and Cleantech: Stimulating Energy Innovation in America's Economic Regions." Washington: Brookings Institution.

--. 2010. "Centers of Invention, Leveraging the Mountain West Innovation Complex for Energy System Transformation." Washington: Brookings Institution

Navigant Consulting. 2010. "The 21st Century Electric Utility: Positioning for a Low-Carbon Future." Boston: Ceres.

Nemet, Gregory. 2009. "Demand-Pull, Technology-Push, and Government-Led Incentives for Non-Incremental Technical Change." *Research Policy* 38: 700-709.

Newell, Richard. 2010. "The Role of Markets and Policies in Developing Innovation for Climate Change Mitigation." *Oxford Review of Economic Policy* 26 (2): 253-269.

Newell, Richard. 2008. "A U.S. Innovation Strategy for Climate Change Mitigation." Washington: Brookings Institution / The Hamilton Project.

Pew Charitable Trusts. 2010. "Global Clean Power: $2.3 Trillion Opportunity." Washington.

Porter, Michael, and Claas van der Linde. 1995. "Toward a New Conception of the Environment-Competitiveness Relationship." *Journal of Economic Perspectives* 9 (4): 97-118.

President's Council of Advisors on Science and Technology. 2010. "Report to the President on Accelerating the Pace of Change in Energy Technologies Through an Integrated Federal Energy Policy." Executive Office of the President.

Saha, Devashree, Sue Gander, and Greg Dierkers. 2011. "State Clean Energy Financing Guidebook." Washington: National Governors Association Center for Best Practices.

Stepp, Matthew, and Robert Atkinson. 2011. "An Innovation Carbon Price: Spurring Clean Energy Innovation while Advancing U.S. Competitiveness." Washington: Information Technology and Innovation Foundation.

Tassey, Gregory. 2010. "Rationales and Mechanisms for Revitalizing US Manufacturing R&D Strategies" Gaithersburg: National Institute of Standards and Technology.

Weissbourd, Robert, and Mark Muro. 2011. "Metropolitan Business Plans: A New Approach to Economic Growth." Washington: Brookings Institution.

World Economic Forum. 2011. "Green Investing 2011: Reducing the Cost of Financing." Geneva.

--. 2010. "Green Investing 2010: Policy Mechanisms to Bridge the Financing Gap." Geneva.

ACKNOWLEDGMENTS

Preparation of this paper and of the database that underlies it has been an unusually collaborative undertaking.

For expert analytic partnership the Brookings team is grateful to the dogged work of Mitchell Horowitz and Martin Grueber at Battelle, supported by John Vitou, Dawn Calvert and Ryan Helwig.

For his pathbreaking work on clean economy measurement and for many contributions to this work the Brookings-Battelle team is also appreciative of Doug Henton of Collaborative Economics.

Otherwise, we would like to acknowledge several other invaluable contributions. For critical guidance, critiques, and nudges we are indebted to those who consulted with us on technical issues: Alan Baum, Randy Becker, Roger Bezdek, Karen Chappel, Jane Evenson, Grant Ferrier, Tracey Grose, David Karpinski, Jed Kolko, Andrew Reamer, Ronald Shadbegian, Greg Tassey, Grahm Toft, Don Walls, Gregg Weeks, and Bob Weissbourd.

For conversations with the Bureau of Labor Statistics team working on these issues we would like to thank Dixie Sommers and Rick Clayton. For hosting useful discussions on various aspects of this work at various stages we want to thank Jeff Finkle, Dick Fleming, Jesse Jenkins, and Andre Pettigrew.

In addition, we would like to thank the following people for their varied and generous contributions: Laurie Actman, William Antholis, Robert Atkinson, Rebecca Bagley, George Bilicic, Drew Bond, Bill Bonvillian, Tom Burke, Michael Carr, Dan Carol, Tom Clark, Will Coleman, John Cleveland, Marc Cummings, Charles Ebinger, Todd Foley, Christina Gabriel, Sue Gander, Jeffrey Genzer, William Harris, Matthew Hourihan, Reed Hundt, Jesse Jenkins, Mark Johnson, Janet Joseph, David Karpinski, Linda Katehi, Richard Kauffman, Kei Koizumi, Nate Lewis, Arun Majumdar, Kristine Mazzei, Lew Milford, Jessica Morey, Adele Morris, Ted Nordhaus, Brian Overington, Ron Pernick, Roberto Porzecanski, Sean Randolph, Elizabeth Redmond, Peter Rothstein, Brian Sager, David Sandalow, Dan Sarewitz, Eric Schinfeld, Rich Sedano, Ryan Sharp, Mike Schwenk, Michael Shellenberger, David Terry, Elizabeth Thorstensen, Alison Wise, and Ethan Zindler.

At Brookings, the project authors want to thank Kenan Fikri and Alec Friedhoff for their hard work and sense of purpose as well as David Jackson for his editorial touch. Other colleagues who have gone above and beyond to help include: Rahsheeda Ali, Alan Berube, Jennifer Bradley, Sue Burnett, Shyamali Choudhury, John Fairbanks, Jeanine Forsythe, Marek Gootman, Rachel Harvey, Carrie Kolasky, Amy Liu, Mariela Martinez, Ellen Ochs, Alicia Posner, Rob Puentes, Neil Ruiz, Chad Shearer, Barbara Semedo, Karen Slachetka, Adie Tomer, Malina Tran, Jennifer Vey, Owen Washburn, and Howard Wial. And as always we thank Bruce Katz for his visionary leadership.

More broadly, the Metropolitan Policy Program at Brookings wishes to thank the Nathan Cummings Foundation, the General Electric Foundation, Living Cities, Inc., and the Surdna Foundation for their support of the program's clean economy work. The John D. and Catherine T. MacArthur Foundation, the Heinz Endowments, the George Gund Foundation, and the F.B. Heron Foundation provide general support for the program's research and policy efforts, and we owe them a debt of gratitude as well.

Finally, we wish to thank the program's Metropolitan Leadership Council, a bipartisan network of individual, corporate, and philanthropic investors that provide us financial support but, more importantly, are true intellectual and strategic partners. While many of these leaders act globally, they retain a commitment to the vitality of their local and regional communities, a rare blend that makes their engagement even more valuable.

ABOUT THE METROPOLITAN POLICY PROGRAM AT BROOKINGS

Created in 1996, the Brookings Institution's Metropolitan Policy Program provides decision makers with cutting-edge research and policy ideas for improving the health and prosperity of cities and metropolitan areas including their component cities, suburbs, and rural areas. To learn more visit www.brookings.edu/metro.

FOR MORE INFORMATION

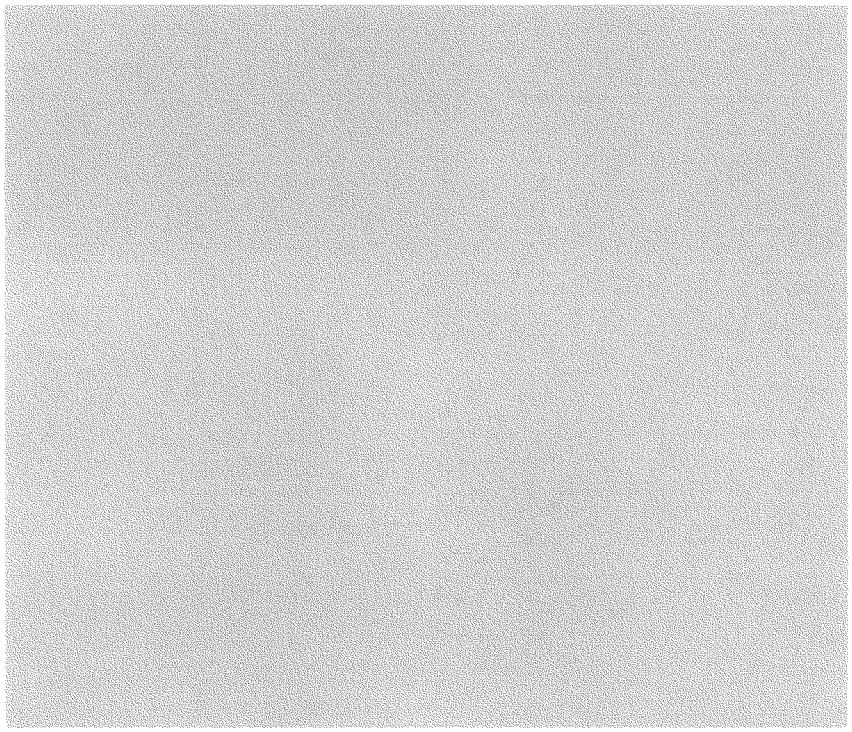
Mark Muro
Senior Fellow and Policy Director
Metropolitan Policy Program at Brookings
202.797.6315
mmuro@brookings.edu

Jonathan Rothwell
Senior Research Analyst
Metropolitan Policy Program at Brookings
202.797.6314
jrothwell@brookings.edu

BROOKINGS
1775 Massachusetts Avenue, NW
Washington D.C. 20036-2188
telephone 202.797.6000
fax 202.797.6004
web site www.brookings.edu

Metropolitan Policy Program
at BROOKINGS

telephone 202.797.6139
fax 202.797.2965
web site www.brookings.edu/metro



OPENING STATEMENT OF HON. BERNARD SANDERS, U.S. SENATOR FROM THE STATE OF VERMONT

Senator SANDERS. Madam Chair, thanks very much for holding this important hearing.

Let me begin by concurring with my friend—and he is my friend—Jim Inhofe. Senator Inhofe and I were on the floor the other day. We have very strong political and philosophical differences. On occasion we agree, on transportation and infrastructure. But certainly on the issue of global warming we have profound disagreements.

Do I have any doubt that Senator Inhofe is sincere and honest about what he believes? I have no doubt about it. And I think he and I are also in agreement that having honest, straightforward debates on this issue is good for the Senate and good for the people of the United States of America.

I may be wrong on this, but I think Senator Inhofe, in many ways, is the leader of the Republicans on the issue of global warming. And I am going to challenge—I think Senator Inhofe's positions are extreme, I think they are dead wrong, and I am curious to see how many of our Republican friends agree with Senator Inhofe. And that is kind of going to be the thrust of the work that I am going to be doing in the near future.

Let me begin by saying that I certainly agree with approximately 98 percent of active publishing climate scientists according to the National Academy of Sciences that global warming is real and that global warming is significantly driven by human activity. I think the broad consensus—not everyone, to be sure, and I think we may have a scientist here today who disagrees—but I think the overwhelming majority of peer reviewed scientists who write on this issue believe A, global warming is real, and B, global warming is significantly caused by human activity.

In my view, as Americans, as part of the greatest country on Earth, we have a moral responsibility and an economic responsibility to lead the world in cutting greenhouse gas emissions and transforming our energy system to energy efficiency and sustainable energies such as solar, wind, geothermal, and biomass.

Senator Inhofe often makes a point, which is valid, which is the United States cannot do it alone. If we did it tomorrow, what about China, what about India, what about Brazil? He is right. But if we do move forward with our technology, with our expertise, we could create jobs in this country, not only transforming our own energy system but leading other nations away from fossil fuel to energy efficiency and sustainable energies.

Now, we have heard a lot, and we have heard it from Senator Inhofe again today, about the economic implications of transforming our energy system. And I wanted to pick up on the point that Senator Boxer has made.

Studies done—there have been a whole bunch of studies done by economic groups, but there was one by the McKinsey consulting firm in 2009, and also the American Council for an Energy Efficient Economy in 2010, confirming that we can meet our 2020 target of reducing emissions 17 percent from 2005 levels through cost effective energy efficiency alone.

Now, I come from a cold weather State. Senator Inhofe comes from a warm State. They use a lot of air conditioning there, I suspect. We use a lot of oil in our State. I can tell you firsthand because we are moving fairly aggressively in Vermont. Not as fast as we should. But we have seen, through weatherization projects, people saving substantial sums of money on their fuel bills, 20, 30, 40 percent, through retrofitting their own homes. And when you do that, you are cutting greenhouse gas emissions by 20, 30, 40 percent.

In Vermont, we have made a good start. We have a long way to go, and we are leading the country. If we do that, we can make huge cuts in greenhouse gas emissions. And you know what else we do? We are going to create jobs in the process of doing that.

A White House Middle Class Task Force report found that we can save up to 40 percent of the energy being used in our homes and our buildings with existing technology. In Vermont, we have weatherized 15,000 homes over the last 10 years, saving the average household over $900 a year on fuel bills. That is a lot of money for a middle class person.

Madam Chair, it is beyond comprehension to me that in the year 2012 we are still giving huge subsidies to fossil fuels, a 19th century technology. And when we hear about so-called Solyndra and other problems, please understand that in a 10-year period we are providing—the Federal Government is providing—over $113 billion to coal, oil, and gas. A 10-year period, over $113 billion. Meanwhile, here in the Senate we face opposition to continuing modest incentives—modest incentives—for solar and wind like the Production Tax Credit or the 1603 Grant Program.

So, it is time to get our act together. I have got to say this. I think, and maybe Senator Inhofe will agree with me on this issue. The whole world is debating global warming. I think most people would agree with the position that many of us, on this side, are taking. Some will agree with what Senator Inhofe is saying. But I think, and Senator Inhofe is right on this issue, we need—we cannot run away from this issue. We have got to put it front and center. We need debates.

I thank Senator Boxer for this hearing today. And I hope we will continue this discussion in this Committee and on the floor of the Senate.

With that, I would yield.

Senator BOXER. Thank you.

Senator Sessions.

OPENING STATEMENT OF HON. JEFF SESSIONS, U.S. SENATOR FROM THE STATE OF ALABAMA

Senator SESSIONS. Thank you.

Well, let me say with regard to Senator Inhofe, I came here, was on this Committee for the first 2 years in the Senate 15 years ago, and I believe that actual fact, empirical data, since that day has validated Senator Inhofe's skepticism and has demonstrated the incorrectness of the computer modeling that the global warming alarmists have produced.

Now, that is fact. That is science. And we are going to talk about that today. And if that is so, the question for the American policy-

makers is how much can we demand this economy pay to meet and confront a fear that is not being proven by empirical data? So, that is the question.

President Obama is engaged in a systematic drive to promote the global warming agenda, and in fact said electricity prices will necessarily skyrocket. So, this is a big issue. We are making this decision right now, and it will be part of the next election, I suppose.

Let us look at this question that has been discussed a lot lately about storms and temperature extremes and how this is a product of global warming. The data does not show that. This is a chart that I hope all of my colleagues will look at. It shows, from NOAA's data, when the record high and record low temperatures for each State were set. The largest number of record highs was set in the 1930s, by far. Twenty-five out of 50 States set their record highs in the 1920s or 1930s. You look at this chart from 1960 through today. Every decade they have had more record cold temperatures than record high temperatures.

Now, I do not know whether that is conclusive evidence about anything. But it does suggest we are not having more extremes, either highs or lows, now than before. But to the extent States have set record temperatures recently, more of them have been record lows than record highs. And Senator Inhofe, you had a record −31 degrees in Oklahoma recently. That is a dramatic thing. We have to look at what is happening.

Now, this is not what the models have said. The computer models say that if CO_2 goes up, temperature will go up. And these are the IPCC scientists, Nobel Prize winners and so forth. That is what they are predicting.

Now, look at this chart. When I came to the Senate, Dr. Christy testified before this Committee, Dr. Lindzen at Harvard, the scientists at MIT, they express skepticism. But the overwhelming group of scientists says the computer models show that we are going to have dramatic changes in our temperature.

This chart reflects the latest computer models, not the ones earlier which were even more extreme. These are the latest computer models. The black line shows what the computer modeling predicted that temperatures would be. These two lower lines, based on satellite data and temperature, show that from about the time that I came to the Senate in 1997, the temperature has basically stayed flat.

Yes, it has increased from 1975, from 1980, to 2010, .2 of 1 degree. Now, you do that over 100 years, that is about .6 of 1 degree if that trend were to follow. But in the last 10 years, we have seen virtually no change in the temperature. This is from empirical data, what is really happening.

So, I guess I am saying, Madam Chairman, we have got to be careful not to ask the American people to bear an immense economic burden to try to defeat a computer modeling that is not coming out to be correct. And we know, throughout history, that temperature has been up and down——

Senator SANDERS. Would the Senator yield for 1 second?

Senator SESSIONS. Yes.

Senator SANDERS. Did you just say, I just wanted to clear the record, that in the last decade we have seen no change in the temperature? Is that what you just said?

Senator SESSIONS. I say that the empirical data, and Dr. Christy will explain that these are not his numbers, but they are the numbers that have been published, show that the temperature is basically the same.

Senator SANDERS. In the last decade?

Senator SESSIONS. Yes.

Senator SANDERS. OK. Thank you.

Senator SESSIONS. Yes, that is the chart. And so, we have heard a lot of spin the other way. I think it is time for the nation to discuss it. If those numbers are wrong, Senator Sanders, so be it. We would have to confront that issue. But I do not think they are wrong. I think they are correct. And that means that we need to be careful about what price we expect the American people to pay to meet the visions of people who are not being proven correct by reality.

Thank you.

Senator BOXER. Senator, may I just say, and we will put in the record an article that talks about credibility in climate change. Ninety-seven to 98 percent of the scientists do not agree with the 1 to 2 percent that you are citing. It is fine. There are still probably 1 to 2 percent of scientists who do not believe that lung cancer is associated with smoking——

Senator SESSIONS. Madam Chairman, I am offended by that.

Senator BOXER. Please do not be——

Senator SESSIONS. I am offended. I did not say anything about the scientists. I said the data shows it is not warming to the degree that a lot of people predicted, not close to that much. And you are asking us to have unprecedented high electricity prices in order to avoid a danger that is not as real as it appears, it seems to me. So we will have a hearing. If I am wrong, I will acknowledge it. But I do not think so.

Senator BOXER. Yes. And I am going to ask the scientists about the data that you have used. All I was pointing out is that the conclusion you are coming to is shared by 1 to 2 percent of the scientists. You should not be offended at that. That is the fact.

Senator SESSIONS. I do not believe that is correct, Madam.

Senator INHOFE. I have to chime in here because I have not had a chance, Madam Chairman, to get my——

Senator BOXER. Go right ahead. And then we will return and go to Senator Cardin.

Senator INHOFE. When we had our, I thought, very enjoyable joint effort on the floor between Senator Sanders and myself on Monday, one of the things that came up about the NAS, the National Academy of Sciences, I do not think we should let it go beyond our recognition that there is a lot of criticism of the NAS and their motives.

Let us keep in mind that the NAS issued a report of the coming ice age in 1975. The U.S. National Academy of Sciences has turned itself into—I am quoting now from Seth Bornstein, which was on the other side of this issue—turned itself into an advocacy group on policy promotion.

I only want to say I disagree with you when you say 1 or 2 percent. I have on my Web site over 1,000 names, and I think it is kind of interesting when you come up with someone who was a skeptic and became an alarmist, that is one out of maybe 1,000 as I mentioned on the floor. So, there is a lot of, the science is clearly divided out in the real world, and that is what this hearing is all about.

Senator BOXER. OK. All right.

Senator SESSIONS. And Madam Chairman——

Senator BOXER. Yes, go right ahead.

Senator SESSIONS. I would acknowledge that we may well have some warming, and it may well be human caused. The disagreement that I am concerned about is how much we can affect it, how much we can afford to spend to alter it, and I am skeptical of the proposal that we have seen.

Senator SANDERS. Would my friend yield?

Senator BOXER. Just one moment. I am going to try to gain some kind of traction here, and then we will, all I am going to do now, instead of getting a debate going, is put into the record, this is something we have not done in a while. It is kind of exciting.

[Laughter.]

Senator INHOFE. Yes, the highway bill got kind of boring there. It really did.

[Laughter.]

Senator BOXER. Yes, we agreed on everything there, which is very unusual.

I am going to put into the record, and I hope Senator Sessions that you will look at this, it is a paper by the journal, it is the National Academy of Sciences. It is our people. And basically, I do not want to get into another argument with you, but they used the figure 97 to 98 percent of climate researchers agreed with the fact that this is occurring now.

So, I am just, you can read this. You may not agree with the——

Senator SESSIONS. Well, that would be 3 percent.

[Laughter.]

Senator BOXER. All right. All right. We will put this on the record. Thank you.

Senator Cardin, thank you for your patience.

[The referenced information follows:]

Expert credibility in climate change

William R. L. Anderegg[a,1], James W. Prall[b], Jacob Harold[c], and Stephen H. Schneider[a,d,1]

[a]Department of Biology, Stanford University, Stanford, CA 94305; [b]Electrical and Computer Engineering, University of Toronto, Toronto, ON, Canada M5S 3G4; [c]William and Flora Hewlett Foundation, Palo Alto, CA 94025; and [d]Woods Institute for the Environment, Stanford University, Stanford, CA 94305

Contributed by Stephen H. Schneider, April 9, 2010 (sent for review December 22, 2009)

Although preliminary estimates from published literature and expert surveys suggest striking agreement among climate scientists on the tenets of anthropogenic climate change (ACC), the American public expresses substantial doubt about both the anthropogenic cause and the level of scientific agreement underpinning ACC. A broad analysis of the climate scientist community itself, the distribution of credibility of dissenting researchers relative to agreeing researchers, and the level of agreement among top climate experts has not been conducted and would inform future ACC discussions. Here, we use an extensive dataset of 1,372 climate researchers and their publication and citation data to show that (*i*) 97–98% of the climate researchers most actively publishing in the field surveyed here support the tenets of ACC outlined by the Intergovernmental Panel on Climate Change, and (*ii*) the relative climate expertise and scientific prominence of the researchers unconvinced of ACC are substantially below that of the convinced researchers.

citation analyses | climate denier | expertise | publication analysis | scientific prominence

Preliminary reviews of scientific literature and surveys of climate scientists indicate striking agreement with the primary conclusions of the Intergovernmental Panel on Climate Change (IPCC): anthropogenic greenhouse gases have been responsible for "most" of the "unequivocal" warming of the Earth's average global temperature over the second half of the 20th century (1–3). Nonetheless, substantial and growing public doubt remains about the anthropogenic cause and scientific agreement about the role of anthropogenic greenhouse gases in climate change (4, 5). A vocal minority of researchers and other critics contest the conclusions of the mainstream scientific assessment, frequently citing large numbers of scientists whom they believe support their claims (6–8). This group, often termed climate change skeptics, contrarians, or deniers, has received large amounts of media attention and wields significant influence in the societal debate about climate change impacts and policy (7, 9–14).

An extensive literature examines what constitutes expertise or credibility in technical and policy-relevant scientific research (15). Though our aim is not to expand upon that literature here, we wish to draw upon several important observations from this literature in examining expert credibility in climate change. First, though the degree of contextual, political, epistemological, and cultural influences in determining who counts as an expert and who is credible remains debated, many scholars acknowledge the need to identify credible experts and account for expert opinion in technical (e.g., science-based) decision-making (15–19). Furthermore, delineating expertise and the relative credibility of claims is critical, especially in areas where it may be difficult for the majority of decision-makers and the lay public to evaluate the full complexities of a technical issue (12, 15). Ultimately, however, societal decisions regarding response to ACC must necessarily include input from many diverse and nonexpert stakeholders.

Because the timeline of decision-making is often more rapid than scientific consensus, examining the landscape of expert opinion can greatly inform such decision-making (15, 19). Here, we examine a metric of climate-specific expertise and a metric of overall scientific prominence as two dimensions of expert credibility in two groups of researchers. We provide a broad assessment of the relative credibility of researchers convinced by the evidence (CE) of ACC and those unconvinced by the evidence (UE) of ACC. Our consideration of UE researchers differs from previous work on climate change skeptics and contrarians in that we primarily focus on researchers that have published extensively in the climate field, although we consider all skeptics/contrarians that have signed prominent statements concerning ACC (6–8). Such expert analysis can illuminate public and policy discussions about ACC and the extent of consensus in the expert scientific community.

We compiled a database of 1,372 climate researchers based on authorship of scientific assessment reports and membership on multisignatory statements about ACC (*SI Materials and Methods*). We tallied the number of climate-relevant publications authored or coauthored by each researcher (defined here as *expertise*) and counted the number of citations for each of the researcher's four highest-cited papers (defined here as *prominence*) using Google Scholar. We then imposed an a priori criterion that a researcher must have authored a minimum of 20 climate publications to be considered a climate researcher, thus reducing the database to 908 researchers. Varying this minimum publication cutoff did not materially alter results (*Materials and Methods*).

We ranked researchers based on the total number of climate publications authored. Though our compiled researcher list is not comprehensive nor designed to be representative of the entire climate science community, we have drawn researchers from the most high-profile reports and public statements about ACC. Therefore, we have likely compiled the strongest and most credentialed researchers in CE and UE groups. Citation and publication analyses must be treated with caution in inferring scientific credibility, but we suggest that our methods and our expertise and prominence criteria provide conservative, robust, and relevant indicators of relative credibility of CE and UE groups of climate researchers (*Materials and Methods*).

Results and Discussion

The UE group comprises only 2% of the top 50 climate researchers as ranked by expertise (number of climate publications), 3% of researchers of the top 100, and 2.5% of the top 200, excluding researchers present in both groups (*Materials and Methods*). This result closely agrees with expert surveys, indicating that ≈97% of self-identified actively publishing climate scientists agree with the tenets of ACC (2). Furthermore, this finding complements direct polling of the climate researcher community, which yields qualitative and self-reported researcher expertise (2). Our findings capture the added dimension of the distribution of researcher expertise, quantify agreement among the highest expertise climate researchers, and provide an independent assessment of level of scientific consensus concerning ACC. In addition to the striking difference in number of expert researchers between CE and UE groups, the distribution of expertise of the UE group is far below that of the CE group (Fig. 1). Mean expertise of the UE group was around half (60 publications) that of the CE group (119 publications; Mann–Whitney U test: W = 57,020; $P < 10^{-14}$), as was median expertise (UE = 34 publications; CE = 84 publications).

Author contributions: W.R.L.A. and J.H designed research; W.R.L.A. and J.W.P. performed research; W.R.L.A. analyzed data; and W.R.L.A., J.W.P., J.H., and S.H.S. wrote the paper.

The authors declare no conflict of interest.

Freely available online through the PNAS open access option.

[1]To whom correspondence may be addressed. E-mail: anderegg@stanford.edu or shs@stanford.edu.

This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1003187107/-/DCSupplemental.

Furthermore, researchers with fewer than 20 climate publications comprise ≈80% the UE group, as opposed to less than 10% of the CE group. This indicates that the bulk of UE researchers on the most prominent multisignatory statements about climate change have not published extensively in the peer-reviewed climate literature.

We examined a subsample of the 50 most-published (highest-expertise) researchers from each group. Such subsampling facilitates comparison of relative expertise between groups (normalizing differences between absolute numbers). This method reveals large differences in relative expertise between CE and UE groups (Fig. 2). Though the top-published researchers in the CE group have an average of 408 climate publications (median = 344), the top UE researchers average only 89 publications (median = 68; Mann–Whitney U test: W = 2,455; $P < 10^{-15}$). Thus, this suggests that not all experts are equal, and top CE researchers have much stronger expertise in climate science than those in the top UE group.

Finally, our prominence criterion provides an independent and approximate estimate of the relative scientific significance of CE and UE publications. Citation analysis complements publication analysis because it can, in general terms, capture the quality and impact of a researcher's contribution—a critical component to overall scientific credibility—as opposed to measuring a researcher's involvement in a field, or expertise (*Materials and Methods*). The citation analysis conducted here further complements the publication analysis because it does not examine solely climate-relevant publications and thus captures highly prominent researchers who may not be directly involved with the climate field.

We examined the top four most-cited papers for each CE and UE researcher with 20 or more climate publications and found immense disparity in scientific prominence between CE and UE communities (Mann–Whitney U test: W = 50,710; $P < 10^{-6}$; Fig. 3). CE researchers' top papers were cited an average of 172 times, compared with 105 times for UE researchers. Because a single, highly cited paper does not establish a highly credible reputation but might instead reflect the controversial nature of that paper (often called the single-paper effect), we also considered the average the citation count of the second through fourth most-highly cited papers of each researcher. Results were robust when only these papers were considered (CE mean: 133; UE mean: 84; Mann–Whitney U test: W = 50,492; $P < 10^{-6}$). Results were robust when all 1,372 researchers, including those with fewer than 20 climate publications, were considered (CE mean: 126; UE mean: 59; Mann–Whitney U test: W = 3.5×10^5; $P < 10^{-15}$). Number of citations is an imperfect but useful benchmark for a group's scientific prominence (*Materials and Methods*), and we show here that even considering all (e.g., climate and nonclimate)

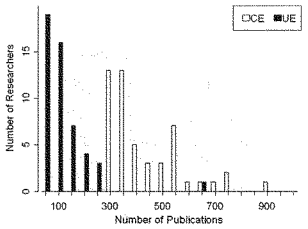


Fig. 2. Distribution of the number of the top 50 most-published researchers from CE and UE categories with a given number of total climate publications. Tick marks indicate the center of right-inclusive categories (e.g., 20–50, 51–100, 101–150, etc.).

publications, the UE researcher group has substantially lower prominence than the CE group.

We provide a large-scale quantitative assessment of the relative level of agreement, expertise, and prominence in the climate researcher community. We show that the expertise and prominence, two integral components of overall expert credibility, of climate researchers convinced by the evidence of ACC vastly overshadows that of the climate change skeptics and contrarians. This divide is even starker when considering the top researchers in each group. Despite media tendencies to present both sides in ACC debates (9), which can contribute to continued public misunderstanding regarding ACC (7, 11, 12, 14), not all climate researchers are equal in scientific credibility and expertise in the climate system. This extensive analysis of the mainstream versus skeptical/contrarian researchers suggests a strong role for considering expert credibility in the relative weight of and attention to these groups of researchers in future discussions in media, policy, and public forums regarding anthropogenic climate change.

Materials and Methods

We compiled a database of 1,372 climate researchers and classified each researcher into two categories: convinced by the evidence (CE) for anthropogenic climate change (ACC) or unconvinced by the evidence (UE) for ACC. We defined CE researchers as those who signed statements broadly agreeing with or directly endorsing the primary tenets of the IPCC Fourth Assessment

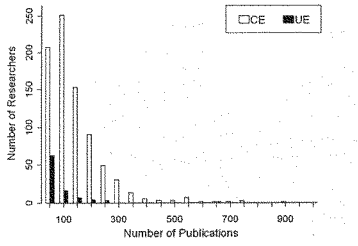


Fig. 1. Distribution of the number of researchers (n = 908) in convinced by the evidence (CE) of anthropogenic climate change and unconvinced by the evidence (UE) categories with a given number of total climate publications. Tick marks indicate the center of right-inclusive categories (e.g., 20–50, 51–100, 101–150, etc.).

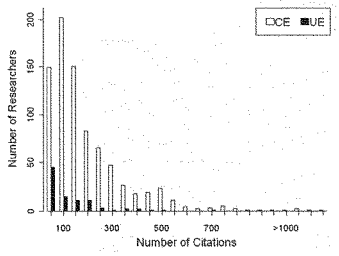


Fig. 3. Distribution of the number of researchers (n = 908) in CE and UE categories with a given number times cited for each researcher's average of the first through fourth most-cited papers. Tick marks indicate the center of right-inclusive categories (e.g., 0–50, 51–100, 101–150, etc.), stepped by increments of 50 until 1,000 citations, and 500 thereafter.

Report that it is "very likely" that anthropogenic greenhouse gases have been responsible for "most" of the "unequivocal" warming of the Earth's average global temperature in the second half of the 20th century (3). We compiled these CE researchers comprehensively from the lists of IPCC AR4 Working Group I Contributors and four prominent scientific statements endorsing the IPCC (n = 903; *SI Materials and Methods*). We defined UE researchers as those who have signed statements strongly dissenting from the views of the IPCC. We compiled UE names comprehensively from 12 of the most prominent statements criticizing the IPCC conclusions (n = 472; *SI Materials and Methods*). Only three researchers were members of both the CE and UE groups (due to their presence on both CE and UE lists) and remained in the dataset, except in calculations of the top 50, 100, and 200 researchers' group membership.

Between December 2008 and July 2009, we collected the number of climate-relevant publications for all 1,372 researchers from Google Scholar (search terms: "author:fi-lastname climate"), as well as the number of times cited for each researcher's four top-cited articles in any field (search term "climate" removed). Overall number of publications was not used because it was not possible to provide accurate publication counts in all cases because of similarly named researchers. We verified, however, author identity for the four top-cited papers by each author.

To examine only researchers with demonstrated climate expertise, we imposed a 20 climate-publications minimum to be considered a climate researcher, bringing the list to 908 researchers (N_{CE} = 817; N_{UE} = 93). Our dataset is not comprehensive of the climate community and therefore does not infer absolute numbers or proportions of all CE versus all UE researchers. We acknowledge that there are other possible and valid approaches to quantifying the level of agreement and relative credibility in the climate science community, including alternate climate researcher cutoffs, publication databases, and search terms to determine climate-relevant publications. However, we provide a useful, conservative, and reasonable approach whose qualitative results are not likely to be affected by the above assumptions. We conducted the above analyses with a climate researcher cutoff of a minimum of 10 and 40 publications, which yielded very little change in the qualitative or strong statistically significant differences between CE and UE groups. Researcher publication and citation counts in Earth Sciences have been found to be largely similar between Google Scholar and other peer-review-only citation indices such as ISI Web of Science (20). Indeed, using Google Scholar provides a more conservative estimate of expertise (e.g., higher levels of publications and more experts considered) because it archives a greater breadth of sources than other citation indices. Our climate-relevant search term does not, understandably, capture all relevant publications and exclude all nonrelevant publications in the detection and attribution of ACC, but we suggest that its generality provides a conservative estimate of expertise (i.e., higher numbers of experts) that should not differentially favor either group.

Publication and citation analyses are not perfect indicators of researcher credibility, but they have been widely used in the natural sciences for comparing research productivity, quality, and prominence (21–24). Furthermore, these methods tend to correlate highly with other estimates of research quality, expertise, and prominence (21–26). These standard publication and citation metrics are often used in many academic fields to inform decisions regarding hiring and tenure. Though these methods explicitly estimate credibility to other academics, which might not directly translate to credibility in broader discourse, polls suggest that about 70% of the American public generally trust scientists' opinions on the environment, making this assessment broadly relevant (27). Criticisms of the two methods center around issues of self-citation, additionality of multiple authors, clique citation, and age demographic (e.g., age distribution where older researchers can accrue more publications and citations) differences between groups (21–26, 28, 29). All of these criticisms are expected to have the least influence at high levels of aggregation (e.g., an entire field) and high levels of citations, both of which are analyzed here (21–23, 25, 28, 29).

Regarding the influence of citation patterns, we acknowledge that it is difficult to quantify potential biases of self-citation or clique citation in the analysis presented here. However, citation analysis research suggests that the potential of these patterns to influence results is likely to decline as sample size of researchers, possible cliques, and papers analyzed for citations considered increases (22, 25–28). By selecting an expansive sample of 1,372 researchers and focusing our analysis only on the researchers' four most-cited papers, we have designed our study to minimize the potential influence of these patterns. Furthermore, we have no a priori basis for assuming any citation (e.g., self-citation rates) or demographic differences (e.g., age effect on publications or citations) between CE and UE groups. Preliminary evidence suggests these differences would likely favor the UE group. From the ~60% of researchers where year of PhD was available, mean year of receiving a PhD for UE researchers was 1977, versus 1987 for CE researchers, implying that UE researchers should have on average more publications due to an age effect alone. Therefore, these methods are likely to provide a reasonable estimate of the preeminent researchers in each group and are useful in comparing the relative expertise and prominence between CE and UE groups.

Ultimately, of course, scientific confidence is earned by the winnowing process of peer review and replication of studies over time. In the meanwhile, given the immediacy attendant to the state of debate over perception of climate science, we must seek estimates while confidence builds. Based on the arguments presented here, we believe our findings capture the differential climate science credentials of the two groups.

ACKNOWLEDGMENTS. We thank C. B. Field, R. Dunlap, M. Mastrandrea, D. L. Karp, A. J. Rominger, and H. V. Moeller for their comments on this paper. Funding for this project was provided by the William and Flora Hewlett Foundation and Stanford University.

1. Oreskes N (2004) Beyond the ivory tower. The scientific consensus on climate change. *Science* 306:1686.
2. Doran PT, Zimmerman MK (2009) Examining the scientific consensus on climate change. *Eos Trans AGU* 90:22–23.
3. IPCC (2007) Summary for policymakers. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*, eds Solomon S, et al. (Cambridge Univ Press, Cambridge, UK).
4. Pew Research Center for People and the Press (2009) Public Praises Science; Scientists Fault Public, Media. Pew Research Center. Available at http://people-press.org/report/528/. Accessed December 1, 2009.
5. Dunlap RE, McCright AM (2008) A widening gap: Republican and Democratic views on climate change. *Environment* 50:26–35.
6. McCright AM, Dunlap RE (2000) Challenging global warming as a social problem: An analysis of the conservative movement's counter-claims. *Soc Probl* 47:499–522.
7. McCright AM, Dunlap RE (2003) Defeating Kyoto: The conservative movement's impact on US climate change policy. *Soc Probl* 50:348–373.
8. Lahsen M (2008) Experiences of modernity in the greenhouse: A cultural analysis of a physicist "trio" supporting the backlash against global warming. *Glob Environ Change* 18:204–219.
9. Boykoff MT, Boykoff JM (2004) Balance as bias: Global warming and the US prestige press. *Glob Environ Change* 14:125–136.
10. Jacques P, Dunlap R, Freeman M (2008) The organisation of denial: Conservative think tanks and environmental scepticism. *Env Polit* 17:349–385.
11. Antilla L (2005) Climate of scepticism: US newspaper coverage of the science of climate change. *Glob Environ Change* 15:338–352.
12. Schneider SH (2009) *Science as a Contact Sport* (National Geographic Society, Washington, DC).
13. Boykoff MT (2009) 'We Speak for the Trees': Media reporting on the environment. *Annu Rev Environ Resour* 34:431–458.
14. Malka A, Krosnick JA, Debell M, Pasek J, Schneider D (2009) Featuring skeptics in news media stories about global warming reduces public beliefs in the seriousness of global warming. Woods Institute for the Environment, Stanford University, Technical Paper. Available at http://woods.stanford.edu/research/global-warming-skeptics.html.
15. Collins HM, Evans R (2002) The third wave of science studies: Studies of expertise and experience. *Soc Stud Sci* 32:235–295.
16. Jasanoff S (2003) Breaking the waves in science studies. *Soc Stud Sci* 33:389–400.
17. Rip A (2003) Constructing expertise. *Soc Stud Sci* 33:419–434.
18. Wynne B (2003) Seasick on the third wave? Subverting the hegemony of propositionalism. *Soc Stud Sci* 33:401–417.
19. Demeritt D (2006) Science studies, climate change and the prospects for constructivist critique. *Econ Soc* 35:453–479.
20. Mikki S (2009) Comparing Google Scholar and ISI Web of Science for earth sciences. *Scientometrics* 10:1–11.
21. Cole J, Cole S (1971) Measuring the quality of sociological research: Problems in the use of the Science Citation Index. *Am Sociol* 6:23–29.
22. Colman AM, Dhillon D, Coulthard B (1995) A bibliometric evaluation of the research performance of British university politics departments: Publications in leading journals. *Scientometrics* 32:49–66.
23. Lindsey D (1989) Using citation counts as a measure of quality in science measuring what's measurable rather than what's valid. *Scientometrics* 15:189–203.
24. Toutkoushian RK, Porter SR, Danielson C, Hollis PR (2003) Using publications counts to measure an institution's research productivity. *Res Higher Educ* 44:121–148.
25. Phelan TJ (1999) A compendium of issues for citation analysis. *Scientometrics* 45:117–136.
26. MacRoberts MH, MacRoberts BR (1996) Problems of citation analysis. *Scientometrics* 36:435–444.
27. The Associated Press–Stanford University Environment Poll (2009) AP–Woods Institute for the Environment at Stanford University. Available at http://www.ap-gfkpoll.com/pdf/AP-Stanford_University_Environment_Poll_Topline.pdf. Accessed February 2, 2010.
28. Aksnes DW (2003) A macro study of self-citation. *Scientometrics* 56:235–246.
29. Kostoff RN (2002) Citation analysis of research performer quality. *Scientometrics* 53:49–71.

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

Senator CARDIN. Thank you, Madam Chair. And let me thank you for calling this hearing on an update of the latest climate change science, and listening to our witnesses, and local adaptation measures, which I really do think is critically important.

I would make just an observation on some of the discussion that has already taken place by my colleagues. When we talk about averages, it can be misleading. One of the consequences of climate change is extreme weather conditions. You can have a drought in one part of the country and a flood in another part of the country, and the equal averages. But the consequences to the people of this nation are severe when we have these extreme weathers.

And Senator Sessions, you mentioned the cost of adaptation, the cost of dealing with these issues. Those who have survived the wildfires have endured a real cost. And those who tried to deal without electricity for over a week in 100 degree weather suffered significant economic losses.

So, I think we have to recognize that extreme weather conditions have a real burden and cost on our society. Those of us who are trying to deal with living on a coast and seeing the rising sea level, wondering how we are going to protect our critical assets, which may be just a homeowner's property, or it may be the Government's Naval Academy, are worried about what the effects of climate change are going to be on the coasts to our country. So, I do think we have to keep this in balance as to the cost to our society.

Climate change is upon us. It is real. This year the United States has seen an increased number of major, deadly storms that are devastating to our communities. We have seen major wildfires, not only in the West but also in the Plains States. We are experiencing a drought that is right now affecting 60 percent of the country and is predicted to cause food prices to rise.

The time to act is now, to harden our infrastructure against extreme heat, to strengthen our electric grid, and to prepare our public health infrastructure to protect our coastal zones and low lying areas.

Today we will hear not only from scientists who will explain to us the data showing how climate is changing, but we will hear from a second panel of policymakers and experts who will tell us the efforts we need to take and projects that are currently underway.

Unfortunately, we are already seeing these problems happening. Just last month, Washington, DC, hit 95 degrees or higher for the 11th straight day, the longest consecutive streak on record. This streak coincided with a devastating multi-day power outage that crippled the Washington area. In my home State of Maryland, hundreds of thousands of folks were without power for days and were forced to contend with extreme heat without air conditioning.

The extreme weather that Marylanders had to deal with this year is just a continuation of the weather emergencies that folks across the country were faced with last year. The administrator of NOAA wrote that last year, and I quote, 14 extreme weather related events caused an incalculable loss of human life and cost the U.S. economy more than $55 billion.

The extreme weather of 2011 has continued into this year, not only with strong storms and intense heat but with dangerous and deadly wildfire seasons in the American West. A brutal heat wave in late June fueled the Wild Oak Canyon fire just outside of Colorado Springs. This fire forced the evacuation of more than 32,000 residents and engulfed almost 350 homes, almost forced the evacuation of the United States Air Force Academy, and tragically killed two people.

Madam Chair, these extreme weather events and increased temperatures are not theoretical. They are happening to us right now. And when those of us in this hearing room leave this building today, we will be walking into one of the worst sustained heat waves on record for this area.

These extremes are the new normal, and they are affecting our nation's infrastructure, our environment, and our public health and safety. It is time we get serious about adapting our infrastructure and systems to these new realities. From our transportation infrastructure to our water systems to public utilities, major systems are being negatively impacted by heat and storms.

Last month at Washington Reagan National Airport, a U.S. Airways regional jet became stuck in the tarmac when temperatures over 100 degrees melted the asphalt. There was a DC train derailed just down the road last month after tracks buckled in the extreme heat. The extreme Derecho storm system that devastated the Maryland, Virginia, and DC area last month left thousands and thousands of people without power for a week during severe heat.

This is a public health issue, a public safety issue. We lost lives. As a result, Governor O'Malley has ordered a special task force to specifically examine solutions for adapting its utility infrastructure to extreme heat and major storms.

Our water infrastructure already is in desperate need of repair. EPA Administrator Lisa Jackson told Congress that adapting to changing hydrological conditions caused by climate change is a significant issue that water systems must act to address. These hydrological changes will likely result in too little water in some places, too much water in other places, and degraded water quality in other areas across the country. According to that study of the National Association of Clean Water Agencies, the costs of dealing with these new realities will approach $1 trillion through 2050.

I am the sponsor of a bill, the Water Infrastructure Resiliency and Sustainability Act, to equip our communities to adapt their water systems to these changing conditions, and I thank the Chair for being a co-sponsor on that legislation.

Madam Chair, I believe that we have a responsibility. I have a responsibility in Maryland, to the people in this country, to do all I can to prepare us for the consequences of climate change. We need to adopt our water infrastructure, our transportation infrastructure, and our electrical grid. We need to help farmers to adapt so that our food supply in the world remains reliable.

We need to adapt our coastal regions to prepare for sea level rise that is already beginning to threaten some of our coastal communities. We need to improve our public health infrastructure to deal with the heat related illnesses that result from these extreme temperatures. In short, we need to act now to protect our communities.

I look forward to the witnesses to give us help and direction of what we can do to help prepare our nation.

Thank you, Madam Chair.

Senator BOXER. Senator Lautenberg, then followed by Senator Whitehouse, unless a Republican comes back.

OPENING STATEMENT OF HON. FRANK R. LAUTENBERG, U.S. SENATOR FROM THE STATE OF NEW JERSEY

Senator LAUTENBERG. Thanks very much, Madam Chairman, for daring to walk into this bonfire of reality.

[Laughter.]

Senator LAUTENBERG. I find it quite incredible that we are still raising the question about whether global warming is a real problem.

In 2003, in this very room, we heard that global warming was the greatest hoax ever perpetrated on the American people. We had a hearing in this building that included a scientist from the Pasteur Institute, and his view was that, and I speak some French poorly but I do like the accent, but I will leave it out for the moment——

[Laughter.]

Senator LAUTENBERG. He said that it is quite incredible. We would know absolutely if we had global warming by the increase in mosquitoes, increases in malaria. And we have not seen that. There cannot be any global warming, he said in quite understandable English.

And we have gone through these, I am going to call them charades for the moment, and our friends on the other side happen to be very likeable, but they are wrong.

[Laughter.]

Senator LAUTENBERG. Anyway, one of the things that we ought to be——

Senator INHOFE. I agree with half your statement.

[Laughter.]

Senator LAUTENBERG. Oh, you are not likeable?

[Laughter.]

Senator LAUTENBERG. I have to ask your kids, I guess.

One of the things that all of us ought to be able to agree on is that we need to get our science from scientists, not politicians nor industry lobbyists. And the scientists at NASA, the National Academy of Sciences and every other leading scientific body have made it clear that global climate change poses a very serious threat to humanity.

In the past, that threat may not have seemed urgent. But in recent months these dangers have become impossible to ignore. Right now, we are seeing the effects of climate change all around us, and we have got to take notice and action immediately because whatever costs we might be seeing increases with now are dwarfed by what could be the result of laissez-faire, leave it alone and not bother with it; it will take care of itself.

Well, last year was the 11th hottest year on record, it was the 11th hottest year on record according to the Commerce Department's Annual State of the Climate Report. Heat waves and flooding to droughts and extreme tornadoes, the U.S. in 2011 experi-

enced some of our most destructive weather ever. And 2012 is on pace to be even worse.

The first 6 months of this year have been the hottest on record for the continental United States, and though our colleague from Alabama has found some solace in the fact that he found places where it is cold, the fact of the matter is that you cannot deny these temperature levels in the recent months. It has led to the worst drought in our nation in more than half a century, resulting in 1,200 counties being declared natural disasters by USDA. And these droughts are killing crops throughout the country, forcing taxpayers to dole out $30 million to $40 million for Federal crop insurance payments, according to a recent report.

Hot and dry conditions have also led to thousands of forest fires throughout the United States. According to NOAA, June wildfires burned more than 1.3 million acres of land, the second most on record. We saw most recently the destruction in Colorado Springs where nearly 350 homes were destroyed at the cost of $9 million.

And we have to be clear. This is just the beginning. The destruction we see throughout the country and globe is simply a thing of signs to come. And if we do not act now to stem the worst effects of climate change, we are looking at once greater problems with hotter temperature, rising sea levels, extreme weather and spread of diseases, climate change poses a serious threat to our way of life.

Nothing, nothing is more important to any of us who have children than to care about the kind of a country, the kind of an environment, we are going to be leaving for them. And we have to remember that the state of the planet that we leave them is the ultimate test of our stewardship.

It has become abundantly clear that we cannot let the doubters deter action any longer because they prefer to ignore the inconvenient facts of an overwhelming scientific consensus. We have got to act on that now.

And I want to call attention, Madam Chairman, to an article that is talked about ravenously, almost, in our Senate, The Conversion of a Climate Change Skeptic. It is an article by a man named Richard Muller. He is a professor of physics at the University of California Berkeley, former MacArthur Foundation Fellow. In a very short paragraph, he said, "Call me a converted skeptic. Three years ago I identified problems in previous climate studies that in my mind threw doubt on the very existence of global warming. Last year, following an intensive research effort involving a dozen scientists, I concluded that global warming was real and that prior estimates of the rate of warming were correct. I am now going a step forward," he says, "humans are almost entirely the cause."

So, I do not know how we dismiss the evidence we see around us and the comments made from reputable organizations. But I think this debate ought to be over, and we ought to move, not discussing today's hearing, it is very important, but in the body that we all spend so much time in, that we ought to get on with trying to solve the problem instead of dismissing it.

Thank you.

Senator BOXER. Thank you very much.

Senator Whitehouse, and then we will get to our panel.

OPENING STATEMENT OF HON. SHELDON WHITEHOUSE, U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Senator WHITEHOUSE. Thank you, Madam Chair. I appreciate the opportunity to participate in this important hearing.

Yesterday marked the end of what is expected to be one of the top five warmest months on record. The USDA recently declared nearly 1,400 counties in 31 States disaster areas as a result of the ongoing drought. NASA and NOAA declared the last decade the warmest decade on record.

So, I am glad we have come together to discuss the science of climate change. Virtually all respected scientific and academic institutions have stated that climate change is happening and that human activities are the driving cause of this change.

Many of us here in Congress received a letter from a number of those institutions back in October 2009 supporting this consensus. This letter was signed by the heads of the organizations listed here. These highly esteemed scientific organizations do not think the jury is out. They recognize that, in fact, the verdict is in, and it is now time for us to act.

As Senator Lautenberg mentioned, Dr. Richard Muller at the Berkeley Earth Surface Temperature Project recently revealed how he has become a converted climate skeptic. In a New York Times op-ed, he cites the findings from his research which was, ironically, partially funded by the Koch brothers, that the Earth's land temperature has increased by 2.5 degrees Fahrenheit in the past 250 years and 1.5 degrees over the past 50 years. He states, "Moreover, it appears likely that essentially all of this increase results from the human emission of greenhouse gases."

Unfortunately, human emission of greenhouse gases is on the rise. This year a monitoring station in the Arctic measured carbon dioxide at 400 parts per million for the first time. This is 50 parts per million higher than the maximum concentration at which scientists predict a stable Earth climate. And it is way out of the bandwidth of 170 to 300 parts per million that has prevailed for the last 8,000 centuries on the Earth's surface.

A 2012 report by the IPCC concludes that climate change increases the risk of heavy precipitation. Rhode Islanders are no strangers to heavy precipitation. In 2010 we saw flooding that exceeded anything Rhode Island had seen since the 1870s when Rhode Island started keeping records.

At the height of the rain, streets in many Rhode Island towns looked more like rivers than roads. Local emergency workers sailed down Providence Street, a main road in West Warwick, by boat and Jet Ski, down a main road on boats and Jet Skis in order to assist residents trapped by the flood waters. While we cannot link that exact storm to climate change, we do know that climate change is increasing the risk of extreme weather like we saw in Rhode Island.

As a New Englander, I was very concerned at a report released this week by Environment America, When It Rains, It Pours, which found that in New England, "Intense rainstorms and snowstorms are happening 85 percent more often than in 1948." Not only are these inundations happening more often, but the largest events are actually dumping more precipitation—around 10 percent more, on

average—across the country. For States like mine, as you can see, these storms are dangerous, expensive, and cause lasting damage.

Ensuring the integrity of our infrastructure in the face of a rapidly changing climate is essential, and our coastal States face a unique set of challenges, what I call the triple whammy. We must adapt not only to extreme temperatures and to extreme weather events, but also to sea level rise.

Long-term data from tide gauges in the historic sailing capital of Newport, Rhode Island, show an increase in average sea level of nearly 10 inches since 1930. At these same tide gauges, measurements show that the rate of sea level rise has increased in the past two decades compared to the rate over the last century. This is consistent with reports that since 1990 sea level has been rising faster than the rates predicted by models used to generate IPCC estimates.

Sea level rise and the increase in storm surge that will accompany it will bring devastation to our doorsteps. Critical infrastructure in at-risk coastal areas, roads, power plants, waste water treatment plants will need to be reinforced or relocated. One consequence of rising sea levels is that local erosion rates in Rhode Island doubled from 1990 to 2006. And some freshwater wetlands near the coast are transitioning to salt marsh.

In Rhode Island, we are trying to be proactive. We have to, frankly, if we want to protect public health and safety. Rhode Island has 19 high hazard dams that have been deemed unsafe by our Department of Environmental Management. We have 6,000 onsite waste water treatment systems located near the coast, several landfills that may be susceptible to coastal erosion, and evacuation routes that could be under water as sea levels rise.

In 2008 our Coastal Resources Management Council adopted a climate change and sea level rise policy to protect public and private property, infrastructure, and economically valuable coastal ecosystem. In 2010 our General Assembly created the Rhode Island Climate Change Commission to study the projected effects of climate change on the State, develop strategies to adapt to those effects, and determine mechanisms to incorporate climate adaptation into existing State and municipal programs.

A draft progress report from the commission lists many ways the State is planning to adapt to climate change including National Grid, our electricity and natural gas utility, undertaking a statewide substation flooding assessment and the Army Corps of Engineers, FEMA, and the Rhode Island Emergency Management Agency conducting a hurricane and flooding evacuation study. And the list goes on and on.

In the town of North Kingston, Rhode Island, they have taken the best elevation data available and modeled 1, 3, and 5 feet of sea level rise, as well as 1 foot of sea level rise plus 3 feet of storm surge. By overlaying these inundation models on top of maps identifying critical infrastructure like roads and emergency routes, railroads, water treatment plants, and estuaries, the town will be able to prioritize transportation, conservation, and relocation projects.

They are also able to quantify the costs of sea level rise. In one small area of the town, 1 foot of sea level rise would put—I am sorry, I have taken over my time. Let me just ask unanimous con-

sent for the remainder of my statement to be put into the record as if I had read it.

Senator BOXER. Absolutely.

Senator WHITEHOUSE. And I thank the Chairman. I just want to emphasize that this is not just a hypothetical problem in Rhode Island. It is real, and real government agencies, real big corporations, real people are facing the facts and having to respond.

[The prepared statement of Senate Whitehouse follows:]

STATEMENT OF HON. SHELDON WHITEHOUSE,
U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Yesterday marked the end of what's expected to be one of the top five warmest months on record. The USDA recently declared nearly 1,400 counties in 31 States disaster areas as a result of the ongoing drought. NASA and NOAA declared the last decade the warmest on record. In 2011 we faced 14 weather related disasters totaling more than a billion dollars each in overall damages and economic costs. And we already have several in 2012.

I am glad we have come together to discuss the science of climate change. Virtually all respected scientific and academic institutions have stated that climate change is happening, and that human activities are the driving cause of this change. Many of us here in Congress received a letter from a number of those institutions in October 2009, stating that:

Observations throughout the world make it clear that climate change is occurring, and rigorous scientific research demonstrates that the greenhouse gases emitted by human activities are the primary driver. These conclusions are based on multiple independent lines of evidence, and contrary assertions are inconsistent with an objective assessment of the vast body of peer reviewed science.

This letter was signed by the heads of the following organizations:

American Association for the Advancement of Science
American Chemical Society
American Geophysical Union
American Institute of Biological Sciences
American Meteorological Society
American Society of Agronomy
American Society of Plant Biologists
American Statistical Association
Association of Ecosystem Research Centers
Botanical Society of America
Crop Science Society of America
Ecological Society of America
Natural Science Collections Alliance
Organization of Biological Field Stations
Society for Industrial and Applied Mathematics
Society of Systematic Biologists
Soil Science Society of America
University Corporation for Atmospheric Research

These highly esteemed scientific organizations don't think the jury's still out. They recognize that in fact, the verdict is in, and it's time to act.

In fact, over the weekend, Dr. Richard Muller, professor of physics at the University of California, Berkeley, director of the Berkeley Earth Surface Temperature project, and a former MacArthur Foundation Fellow, revealed how he's become a converted climate skeptic in a New York Times op-ed. He cites findings from his research—partially funded by the Koch brothers, ironically—that the Earth's land temperature has increased by 2 and a half degrees Fahrenheit in the past 250 years and 1 and a half degrees over the past 50 years. He states, "Moreover, it appears likely that essentially all of this increase results from the human emission of greenhouse gases."

Unfortunately, human emission of greenhouse gases is only on the rise. In 2011 the Mauna Loa Observatory documented the biggest annual jump in carbon dioxide. And this year a monitoring station in the Arctic measured carbon dioxide at 400 ppm for the first time. This is 50 ppm higher than the maximum concentration at which scientists predict a stable climate. And this is well outside the 170–300 ppm range that has existed for the past 8,000 centuries.

A 2012 report by the IPCC concludes that climate change increases the risk of heavy precipitation. Rhode Islanders are no stranger to heavy precipitation. In 2010

we saw flooding that exceeded anything we've seen since the 1870s when Rhode Island started keeping records. At the height of the rains, streets in many Rhode Island towns looked more like rivers than roads. Local emergency workers sailed down Providence Street, a main road in West Warwick, by boat and Jet Ski; down a main road on boats and Jet Skis; in order to assist residents trapped by the flood waters.

While we can't link that exact storm to climate change, we know that climate change is increasing the risk of extreme weather events like this one. As a New Englander, I was concerned by a report released this week by Environment America. "When It Rains, It Pours," found that, in New England, "intense rainstorms and snowstorms [are] happening 85 percent more often than in 1948. The frequency of intense rain or snowstorms nearly doubled in Vermont and Rhode Island, and more than doubled in New Hampshire." And not only are these inundations happening more often, but the largest events are actually dumping more precipitation—around 10 percent more on average—across the country. For States like mine, as you can see, these storms are dangerous, expensive, and cause lasting damage.

We are moving down a troublesome and unknown path where the best thing we can do is prepare for dramatic environmental shifts. We must look to science and scientists and use the best available data to protect and prepare both our natural and built environments, which sustain us and our economy. Ensuring the integrity of our infrastructure in the face of a rapidly changing climate is essential. Coastal States face a unique set of challenges—what I call a triple whammy—as we must adapt not only to extreme temperatures and weather but also to sea level rise.

As average global temperatures rise, less water will be stored in snowpack and the ice sheets of Antarctica and Greenland. We also know that at higher temperatures water expands to greater volume. Predictions for sea level rise range from 20–39 inches by the year 2100, with recent studies showing that the numbers could be even higher due to greater than expected melting of glaciers and ice sheets.

Long-term data from tide gauges in the historic sailing capital of Newport, Rhode Island, show an increase in average sea level of nearly 10 inches since 1930. At these same tide gauges, measurements show that the rate of sea level rise has increased in the past two decades compared to the rate over the last century. This is consistent with reports that since 1990 sea level has been rising faster than the rate predicted by models used to generate IPCC estimates.

Sea level rise and the increase in storm surges that will accompany it will bring devastation to our doorsteps. Critical infrastructure in at-risk coastal area—roads, power plants, waste water treatment plants—will need to be reinforced or relocated. Additionally, our estuaries, marshes, and barrier islands that act as natural filtration systems and buffers against storms will be inundated, with little time or space to retreat and move inland as they have in the past.

One consequence of rising sea levels is that local erosion rates in Rhode Island doubled from 1990 to 2006, and some freshwater wetlands near the coast are transitioning to salt marsh. Increased sea level and erosion puts critical public infrastructure at risk. In Rhode Island, we have a small but vibrant coastal community, Matunuck, where beaches have eroded 20 feet over the past 12 years. The town faces very difficult decisions as the only road connecting about 1,600 residents and several restaurants and businesses is protected by less than a dozen feet of sand. The road, which provides access for emergency vehicles and lies on top of the water main, must be protected. But what are the costs of protecting this piece of road for areas nearby or further down shore? Often, when you protect one area of beach from erosion by hardening or altering the shoreline, you do so at the sacrifice of other areas.

These are not easy decisions for communities with limited resources when lives and livelihoods are at risk, and climate change will only make things worse. To best protect infrastructure and the communities and families that live in at-risk areas, we must plan ahead, using the best and most reliable science, and be able to prioritize adaptation efforts.

In North Carolina, the State legislature considered a measure that would have severely restricted the ability of their Coastal Resources Commission to employ scientific estimates of future sea level rise. This type of thinking will cost money and lives in the future.

In Rhode Island, we're taking a different approach. We have to if we want to protect public health and safety. Rhode Island has 19 "high hazard" dams that have been deemed "unsafe" by our Department of Environmental Management. We have 6,000 onsite waste water treatment systems located near the coast, several landfills that may be susceptible to coastal erosion, and evacuation routes that could be underwater as sea levels rise.

In 2008 our Coastal Resources Management Council adopted a Climate Change and Sea Level Rise Policy to protect public and private property, infrastructure, and economically valuable coastal ecosystems. The policy states the following:

• The Council will integrate climate change and sea level rise scenarios into its operations to prepare Rhode Island for these new, evolving conditions and make our coastal areas more resilient.

• It is the Council's policy to accommodate a base rate of expected 3–5 foot rise in sea level by the year 2100 in the siting, design, and implementation of public and private coastal activities and to ensure proactive stewardship of coastal ecosystems under these changing conditions. It should be noted that the 3–5 foot rate of sea level rise assumption embedded in this policy is relatively narrow and low. The Council recognizes that the lower the sea level rise estimate used, the greater the risk that policies and efforts to adapt to sea level rise and climate change will prove to be inadequate.

This policy is already helping the State make smart decisions. For example, when a new pump station was needed at a sewage treatment plant, CRMC looked at sea level rise models before determining where it should go, avoiding future relocation costs or malfunction in the face of flash flooding and sea level rise.

In 2010 our General Assembly created the Rhode Island Climate Change Commission to study the projected impacts of climate change on the State, develop strategies to adapt to those impacts, and determine mechanisms to incorporate climate adaptation into existing State and municipal programs. A draft progress report from the Commission lists many ways the State is planning to adapt to climate change, including:

• Creating a "Structural Concept and Contingency Plan to Inundation of the Ferry Terminals and Island Roadway Systems";

• Creating the "Central Landfill Disaster Preparedness Plan";

• National Grid, our electricity and natural gas utility, undertaking a "Statewide Substation Flooding Assessment"; and

• The Army Corps of Engineers, FEMA, and the Rhode Island Emergency Management Agency conducting a "Hurricane and Flooding Evacuation Study."

The list goes on and on.

In the town of North Kingston, Rhode Island, they have taken the best elevation data available and modeled 1, 3, and 5 feet of sea level rise, as well as 1 foot of sea level rise plus 3 feet of storm surge. By overlaying these inundation models on top of maps identifying critical infrastructure like roads, emergency routes, railroads, water treatment plants, and estuaries the town will be able to prioritize transportation, conservation, and relocation projects. They are also able to quantify the costs of sea level rise. In one small area of the town, 1 foot of sea level rise would put 2 buildings, valued at $1.3 million, underwater. Five feet of sea level rise, however, jeopardizes 116 buildings valued at $91 million.

Similarly, by modeling how sea level rise will impact estuaries, towns can preserve areas that will stay wetlands or undeveloped areas that will become wetlands in the future, as opposed to areas that will be lost. Estuaries act as nurseries for our hugely valuable fisheries and protect our homes, buildings, and communities from storm surge. There is already limited funding to protect these important ecosystems, and this kind of planning promotes efficiency in spending.

Now is the time to start making policy that helps us all adapt to the emerging scientific reality that our actions affect our environment.

Nature could not be giving us clearer warnings. Whatever higher power gave us our advanced human capacity for perception, calculation, analysis, deduction, and foresight has lain out before us more than enough information to make the right decisions. Only a wild and reckless greed, or a fatal hubris, could blind us to our world's distress signals. Fortunately, these human capacities provide us everything we need to act responsibly, if only we will.

Senator BOXER. Thank you very much.

Now, we turn to our esteemed panel. We have two majority witnesses and one minority witness.

Our first witness is Dr. Christopher B. Field, Founding Director, Carnegie Institution of Washington's Department of Global Ecology, Professor of Biology and Environmental Earth Science, Freeman Spogli Institute for International Studies, Senior Fellow, Stanford University.

We welcome you.

We ask all of our witnesses to try to stick to 5 minutes. We will give you a little leeway there, but if you can keep it to 5.

STATEMENT OF CHRISTOPHER B. FIELD, PH.D., FOUNDING DIRECTOR, CARNEGIE INSTITUTION OF WASHINGTON'S DEPARTMENT OF GLOBAL ECOLOGY, PROFESSOR OF BIOLOGY AND ENVIRONMENTAL EARTH SCIENCE, FREEMAN SPOGLI INSTITUTE FOR INTERNATIONAL STUDIES, SENIOR FELLOW, STANFORD UNIVERSITY

Mr. FIELD. Thank you, Chairman Boxer, Ranking Member Inhofe, and Members of the Committee. I am delighted to appear before you today to discuss one of the most important issues facing our nation, the challenge of a changing climate.

The link between climate change and the kinds of climate extremes that lead to disasters is clear. To quote the latest report of the Intergovernmental Panel on Climate Change, a changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events and can result in unprecedented extreme weather and climate events.

My name is Chris Field. I am a working scientist. Over the past 35 years I have published more than 200 peer reviewed papers about all aspects of climate change. In 2008 I was asked by the Bush administration to help coordinate the work of the Intergovernmental Panel on Climate Change or IPCC. That is work that I now do as an unpaid volunteer.

In my testimony today, I will address three aspects of the state of science of climate change. Three key points. The first, climate change is real. Second, some kinds of extreme events are already increasing. Third, climate change leads to risks in the kinds of extreme events that can lead to disasters.

Climate change science is complex, technical, and rapidly changing. We are very fortunate in climate science to be able to take advantage of a wide range of comprehensive assessments so that all the scientists who are working in this complicated topic can bring their ideas together, sort them out, see which ones stand the test of time, and present balanced, authoritative overviews of what is known and what is not known about climate science.

And recent assessments overwhelmingly support the conclusion that "Climate change is occurring. It is very likely caused primarily by the emission of greenhouse gases from human activities and poses significant risk for a range of human and natural systems." This is from the 2011 report of the U.S. National Academy of Sciences and is absolutely characteristic of what is coming from all of the major assessments by national academies of scientists from around the world and the Intergovernmental Panel on Climate Change.

The conclusion that warming in the climate system is unequivocal is supported by many kinds of data. Could I have the first chart, please? Several groups have analyzed weather station data, and they all reach strikingly similar conclusions. As you can see from the figure on the easel, global land areas warmed by about 2 degrees Fahrenheit since 1900. We really have reached the point where the question of whether the Earth is warming is no longer in doubt.

In its 2012 report on extreme events and disasters, the IPCC concludes, based on observations, not on models, that we have experienced increases in three kinds of extremes—extremes of high temperatures, extremes that are associated with intense precipitation, and extremes that are associated with high sea levels, basically storm surge. It also provides evidence that human caused climate change has played a role in these kinds of extremes.

Now, for some kinds of climate related extremes, we do not yet know the strength of the link with climate change. But for many other categories of extreme climate and weather events, the pattern is increasingly clear. Climate change is shifting the risk of hitting an extreme. The IPCC concludes that climate change increases the risk of heat waves, heavy precipitation, and droughts for most land areas.

These findings about risk do not speak directly to the role of climate change in any particular event. In this sense, the increase in risk of a climate extreme from climate change is parallel to the increasing risk of an accident from speeding in a car. We can point clearly to the causal mechanism, but it is still difficult to predict exactly when or where the crisis, either the accident from speeding in a car or the disaster that is related to climate change, will occur. But still, we can still have high confidence in the driving mechanism. It is also important to recognize that just as many factors influence the risk of a car accident.

The risk of climate related disasters is also influenced by a number of things like disaster preparation and early warning. As a result of recent progress in understanding the role of climate change and the risks of extremes, it is now possible to quantify the way that climate change alters the risk of certain kinds of extremes. For example, climate change at least doubled the risk of the European heat wave of 2003. This was a major event that resulted in tens of thousands of excess mortalities.

For the 2011 Texas drought, La Niña—this is the cold water in the eastern Pacific—played a role. But recent research by David Rupp and colleagues indicates that there is now more than 20 times greater likelihood of high temperatures during a La Niña than in the 1960s. More than 20 times greater likelihood of high temperatures now than in the 1960s.

Let me conclude with a comment about the 2011 Texas drought. The U.S. is an agricultural superpower. It is our responsibility, I believe, to maintain the ability of our citizens and the people of Texas to sustain their role as the nation's second largest producer of agricultural income. For this hope to be realized, the farmers and ranchers of Texas have to have access to the best available information so that they can make sound choices about their future and their children's future.

In summary, there is no doubt that the climate has changed and that changes will continue with an amount that is determined by the amount of heat trapping gases that we release into the atmosphere. There is also no doubt that a changing climate changes the risk of extremes, including extremes that can lead to disasters——

Senator BOXER. Ten seconds; close it up.

Mr. FIELD [continuing]. Recognizing these changing risks is critical, if we are to make good decisions about the challenges of pro-

tecting and enhancing our natural legacy, our economy, and our people.

Thank you very much.

[The prepared statement of Mr. Field follows:]

Testimony of

Christopher B. Field

Director, Department of Global Ecology

Carnegie Institution for Science

Professor, Departments of Biology and Environmental Earth System Science

Stanford University

before

United States Senate Committee on Environment and Public Works

on

Update on the Latest Climate Change Science

1 August 2012

Thank you Chairman Boxer, Ranking Member Inhofe, and members of the Committee. I am delighted to appear before you today to discuss one of the most important issues facing the nation – the serious challenge of a changing climate and especially the links between climate change and extreme events. As the US copes with the aftermath of last year's record-breaking series of 14 billion-dollar climate-related disasters and this year's massive wildfires and storms, it is critical to understand that the link between climate change and the kinds of extremes that lead to disasters is clear. Overwhelming evidence supports the conclusion in the latest report of the Intergovernmental Panel on Climate Change that "A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events." (IPCC 2012).

My name is Dr. Christopher Field. I am Director of the Department of Global Ecology of the Carnegie Institution for Science and Professor in the Departments of Biology and Environmental Earth System Science at Stanford University. Based on work over more than 35 years, I have published more than 200 peer-reviewed papers on many aspects of climate science, including field experiments, analyses of large-scale climate and agriculture databases, work with satellite observations, and studies with climate models. I am an elected member of the US National Academy of Sciences. In 2008, the Bush administration asked me to help coordinate the work of the IPCC, the Intergovernmental Panel on Climate Change. I currently co-chair Working Group II of the IPCC, which I do as an unpaid volunteer. In my testimony today, I will be presenting information from a variety of sources, including the assessments from the US National Academy of Sciences, the US National Oceanic and Atmospheric Administration, the IPCC, and papers in the technical scientific literature.

My testimony today will address the state of scientific knowledge concerning three key points.

1) Overwhelming evidence establishes that climate change is real
2) Strong evidence indicates that some kinds of climate extremes are already changing
3) Climate change leads to changes in the risk of extreme events that can lead to disasters

Thousands of scientists are carefully studying the data about climate change. Their observations are published in thousands of papers in the scientific literature. These scientists also participate in assessments of the state of knowledge, often coordinated by national academies of science or scientific societies. These assessments to evaluate the vast and rapidly growing scientific literature on climate change overwhelmingly support the conclusions that "Climate change is occurring, is very likely caused primarily by the emission of greenhouse gases from human activities, and poses significant risks for a range of human and natural systems." This comes from the 2011 Final Report of the US National Academy of Sciences, "America's Climate Choices" (National Research Council 2011). The IPCC, which provides a mechanism for all of the world's climate scientists to collaborate in assessing what is known and what is not known about the science of climate change, in its 2007 report (IPCC 2007) concluded that "Warming of the climate system is unequivocal". "The evidence is incontrovertible: Global warming is occurring." is the wording used in the statement of the American Physical Society (American Physical Society 2010).

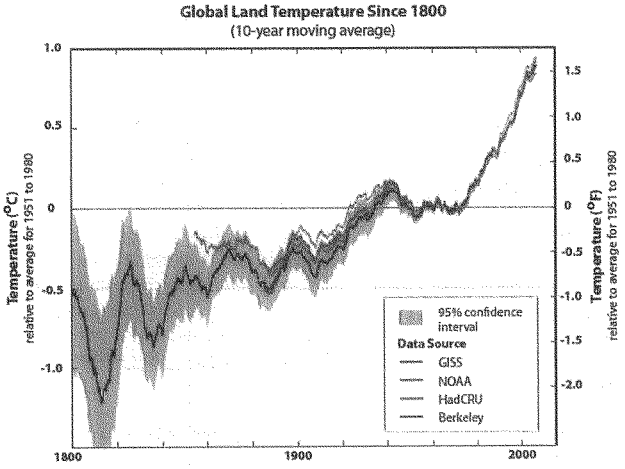


Figure 1: Global land temperature since, 1800, based on weather station data. The references for the published studies are: (Hansen et al. 2010), (Jones et al. , NOAA 2012b), (Smith and Reynolds 2005). The Berkeley data are online at: http://berkeleyearth.org/.

Several research groups have analyzed the records from weather stations, and these groups reach strikingly similar conclusions about the historical trend. Relative to 1900, the global land area has warmed by about 2°F (Figure 1). The record shows warming from 1900 to about 1940, a period of relatively constant temperatures from 1940 until about 1970, and rapid warming since 1980. In the past, there were some indications that trends from temperatures measured by satellites showed a different pattern, but several recent analyses demonstrate that, when the satellite data are analyzed carefully, the trends from the land-based weather stations and the satellites are consistent (Karl et al. 2006). We have reached the stage where the question of whether Earth is warming is not in doubt.

In its 2012 report "Managing the risks of extreme events and disasters to advance climate change adaptation", the IPCC (IPCC 2012) concluded that "A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events." Based on the analysis of historical records since 1950, the report identified trends of increasing extreme hot temperatures, intense precipitation, and extreme high sea levels. It concluded that there is evidence that human-caused climate change played a role in these changes in extremes. The report identified some areas where droughts have become longer and more intense (including southern Europe and West Africa), but others where droughts have become less frequent, less intense, or shorter.

The trend in extreme hot temperatures is striking in the proportion of record-setting daily highs versus record daily lows in station data from the US National Weather Service (Figure 2). In an unchanging climate, the expectation is that, for any given date, one should see approximately equal numbers of record high temperatures and record low temperatures. For the US, that is exactly the pattern for 1950 to 1989, but the proportion of record-setting highs has been growing and the proportion of record lows has been shrinking since then. From 1990 to 2008, 63% of the daily records were high temperatures and only 37% were lows. In 2009, 55% of the records were record highs. The numbers were 69% record highs in 2010 and 73% record highs in 2011. For the first six months of 2012, 92% of the daily temperature records in the US were record highs. Through the first 23 days of July, there were 20 record high temperatures for every record low.

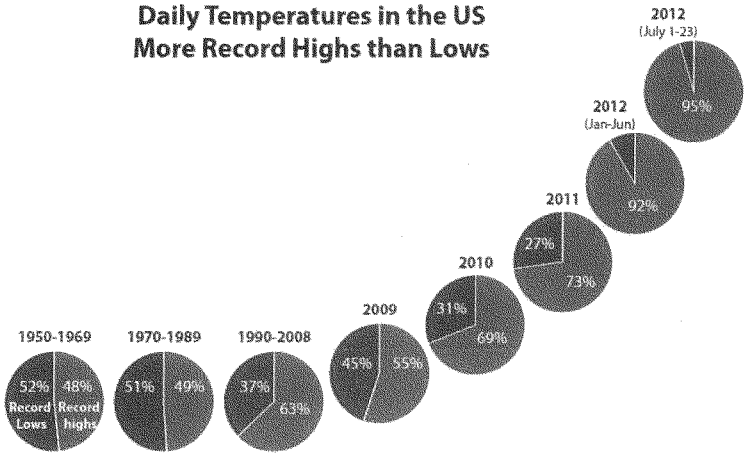


Figure 2: Changing pattern of daily temperature records in the US, based on US weather stations. If the climate is not changing, the number of record-setting high temperatures should be approximately the same as the number of record-setting low temperatures. References for the published study and the newer data are: (Meehl et al. 2009) (http://www.ncdc.noaa.gov/extremes/records/).

The US experienced 14 billion-dollar disasters in 2011, a record that far surpasses the previous maximum of 9 (NOAA 2012a). The 2011 disasters included a blizzard, tornadoes, floods, severe weather, a hurricane, a tropical storm, drought and heat wave, and wildfires. In 2012, we have already experienced horrifying wildfires, a powerful windstorm that hit Washington DC, heat waves in much of the country, and a massive drought currently affecting more of the US than any drought since 1988.

For several of these categories of disasters, the strength of any linkage to climate change, if there is one, is not known. Specifically, the IPCC (IPCC 2012) did not identify a trend or express confidence in projections concerning tornadoes and other small-area events. The evidence on hurricanes is mixed.

For other categories of climate and weather extremes, the pattern is increasingly clear. Climate change is shifting the risk of hitting an extreme. The IPCC (IPCC 2012) concludes that climate change increases the risk of heat waves (90% or greater probability), heavy precipitation (66% or greater probability), and droughts (medium confidence) for most land areas. These findings about risk do not speak directly to the role of climate change in any particular event. In this sense, the increase in risk of a weather extreme from climate change is parallel to the increasing risk of an accident from speeding in a car. The evidence pointing to the driving force behind the extra risk (either the climate change of the excess speed) can be strong, but it is still difficult to predict exactly when and where disaster might occur. And just as many factors influence the risk of a car accident, the risk of a weather-related disaster is strongly influenced by disaster preparations, early warning, and the integrity of local infrastructure like buildings, roads, and the electricity grid.

Understanding the role of climate change in the risk of extremes is one of the most active areas of climate science (Peterson et al. 2012). As a result of rapid progress over the last few years, it is now feasible to quantify the way that climate change alters the risk of certain events or series of events. For example, climate change at least doubled the risk of the European heat wave of 2003 (Stott et al. 2004), a high-impact extreme that led to tens of thousands of premature deaths, especially among the elderly or infirm (Robine et al. 2008). On the other hand, there is no evidence that climate change played a role in the serious flooding in Thailand in 2011 (Van Oldenborgh et al. 2012). The primary causal agent there was altered land management. For the 2011 Texas drought, La Niña (cold water in the eastern Pacific) played a role, but recent research by David Rupp and colleagues concludes that, in a La Niña period, extreme heat is now 20 times more likely than in the 1960s (Rupp et al. 2012).

Let me conclude with a comment about the way I see my responsibility as a scientist, particularly in the context of the 2011 Texas drought. Our nation is an agricultural superpower, and farming and ranching are among our highest callings. I hope Texans have the opportunity to maintain Texas as the nation's second largest source of agriculture income. For this hope to be realized, the farmers and ranchers of Texas need to have access to the best available information about the risks they face and their options for dealing with them. Climate change is altering those risks, and the people of Texas, indeed the people of the United States, need to know this to make good decisions about their future and their children's future.

In summary, there is no doubt that climate has changed and that changes will continue in the future, with human emissions of heat-trapping gases playing a major role. There is also no doubt that a changing climate changes the risk of extremes, including extremes that can lead to disaster. It is only by understanding those risks in the most clear-headed, objective way possible that we, as a nation, can

make good decisions about the challenges of protecting and enhancing our natural legacy, our economy, and our people.

References:

American Physical Society. 2010. National Policy 07.1 Climate Change. http://www.aps.org/policy/statements/07_1.cfm.

Hansen, J., R. Ruedy, M. Sato, and K. Lo. 2010. Global surface temperature change. Rev. Geophys **48**:29.

IPCC. 2007. Summary for Policymakers. Pages 1-21 *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M.Tignor, and H. L. Miller, editors. Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, UK and New York, NY, USA.

Jones, P., D. Lister, T. Osborn, C. Harpham, M. Salmon, and C. Morice. Hemispheric and large-scale land surface air temperature variations: An extensive revision and an update to 2010. Journal of Geophysical Research.

Karl, T. R., S. J. Hassol, C. D. Miller, and W. L. Murray, editors. 2006. Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences. A Report by the Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC. US Global Change Research Program, Washongton, D. C.

Meehl, G. A., C. Tebaldi, G. Walton, D. Easterling, and L. McDaniel. 2009. Relative increase of record high maximum temperatures compared to record low minimum temperatures in the US. Geophysical Research Letters **36**:L23701.

National Research Council. 2011. America's Climate Choices. National Academies Press, Washington DC.

NOAA. 2012a. Extreme Weather 2011. http://www.noaa.gov/extreme2011/.

NOAA. 2012b. U.S. Records, National Oceanic and Atmospheric Administration, National Climatic Data Center. http://www.ncdc.noaa.gov/extremes/records/.

Peterson, T. C., P. A. Stott, and S. Herring. 2012. Explaining Extreme Events of 2011 from a Climate Perspective. Bulletin of the American Meteorological Society **93**:1041-1067.

Robine, J.-M., S. L. K. Cheung, S. Le Roy, H. Van Oyen, C. Griffiths, J.-P. Michel, and F. R. Herrmann. 2008. Death toll exceeded 70,000 in Europe during the summer of 2003. Comptes Rendus Biologies **331**:171-178.

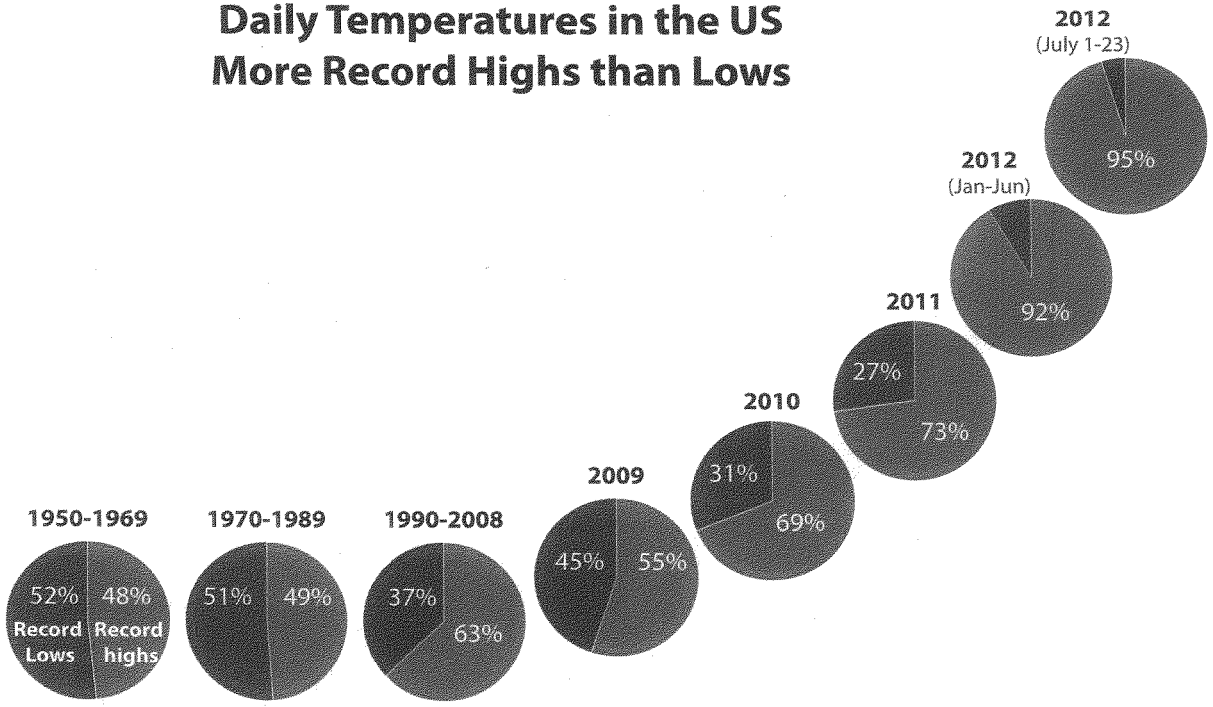
Rupp, D. E., P. Mote, N. Massey, C. Rye, R. Jones, and M. Allen. 2012. Did human influence on climate make the 2011 Texas drought more probable? Bulletin of the American Meteorological Society **93**:1052-1057.

Smith, T. M. and R. W. Reynolds. 2005. A Global Merged Land–Air–Sea Surface Temperature Reconstruction Based on Historical Observations (1880–1997). Journal of Climate **18**:2021-2036.

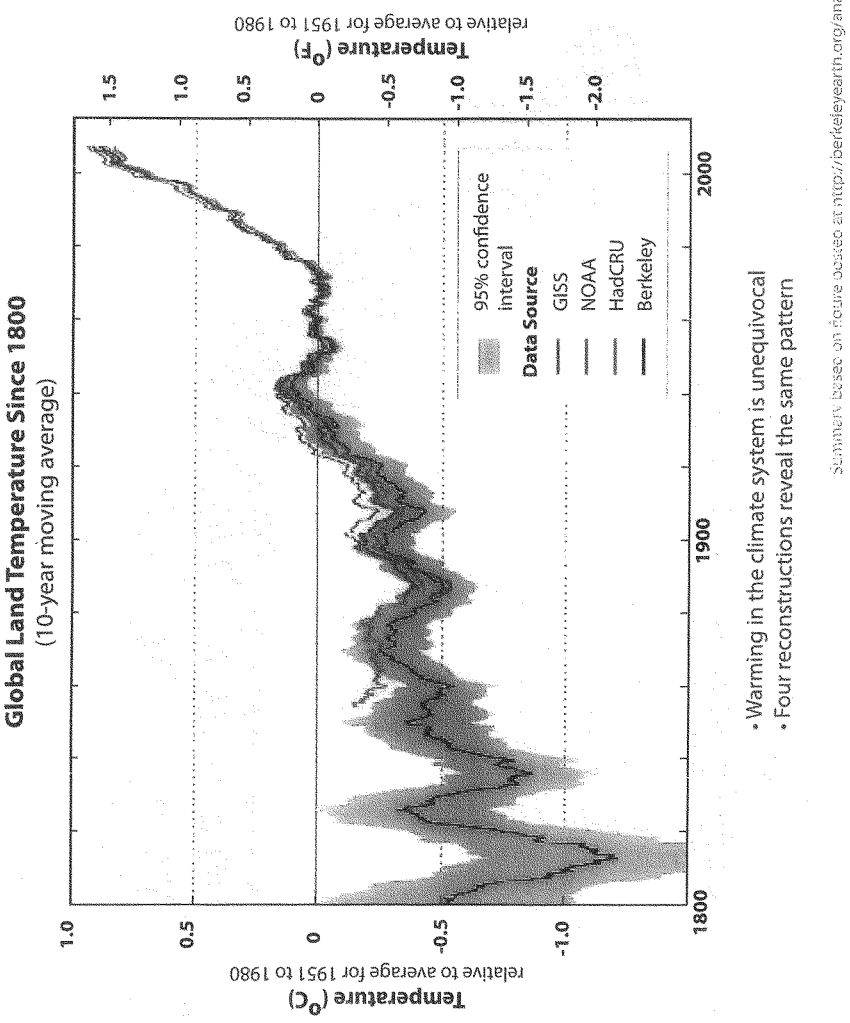
Stott, P., D. Stone, and M. Allen. 2004. Human contribution to the European heatwave of 2003. Nature **432**:610-614.

Van Oldenborgh, G., A. Van Urk, and M. Allen. 2012. The absence of a role of climate change in the 2011 Thailand floods. Bulletin of the American Meteorological Society **93**:1047-1051.

Daily Temperatures in the US
More Record Highs than Lows



Source: Meehl et al. Geophys Res Let 2009 (for 1950-2008) and NOAA NCDC (for 2009-2012)


Global Land Temperature Since 1800
(10-year moving average)
Temperature (°C)
relative to average for 1951 to 1980
Temperature (°F)
relative to average for 1951 to 1980
1.0
0.5
0
-0.5
-1.0
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
1800
1900
2000
95% confidence interval
Data Source
GISS
NOAA
HadCRU
Berkeley
• Warming in the climate system is unequivocal
• Four reconstructions reveal the same pattern
Summary based on figure based at http://berkeleyearth.org/analysis/

Responses to Follow-Up Questions
1 August 2012 hearing
Update on the Latest Climate Change Science and Local Adaptation Measures
Committee on Environment and Public Works
US Senate

Christopher Field
8 January 2012

Questions from Senator Boxer

1) Your testimony states a key conclusion of a recent report about the impacts of climate change on extreme weather: "A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events."

   Could you please describe the implications of a change in the frequency of extremes and how these changes could impact people's lives?

   In general, climate poses risks to people, infrastructure, and ecosystems mainly under extreme conditions. People, infrastructure, and ecosystems are usually adapted to typical conditions, so that they do not experience typical or nearly typical conditions as stressing the system. It is when weather events move things away from typical conditions that things start to break. Weather extremes can turn into disasters when conditions are too hot, too cold, too wet, too dry, or too windy. Over the last decades, economic losses from disasters in the US have typically been in the tens of billions of dollars a year, with the highest losses in 2005, the year of hurricane Katrina.

   The risk that a climate or weather extreme turns into a disaster depends not only on the weather event but also on the exposure (the amount of assets in harm's way) and the vulnerability or susceptibility to damage. Globally, economic disaster losses have increased in the last 30 years, largely as a consequence of increasing exposure. During this period, most of the economic losses from climate-related disasters have been concentrated in the world's developed countries. The overwhelming majority of the loss of life, approximately 95%, has been in developing countries.

   In general, disaster losses are decreased when people and societies are prepared. Historically, preparation is better for types of disasters that have occurred recently. One of the biggest challenges with climate change is that the traditional pattern of basing disaster risk reduction on historical experience is not effective. Protecting people and societies will require new approaches to risk communication and risk management. The prospect of changing risks places a high priority on effective planning and learning by doing.

2) The 2012 IPCC report which you co-authored states: "Extreme events will have greater impacts on sectors with closer links to climate, such as water, agriculture, and food security, forestry, health, and tourism..."

In California in 2010, agriculture had revenues of $37.5 billion and tourism supported nearly 900,000 jobs and nearly $90 billion in direct spending.

Could more frequent and intense extreme weather events impact these types of key economic sectors?

Yes, agriculture and tourism are among the activities that are generally most sensitive to climate and to climate extremes. Agriculture in California, the nation's most important agricultural state in terms of economic value of the production, is especially vulnerable to climate for two main reasons. The first is that water shortages are always a risk for California agriculture. Warming poses grave risks for the ability of the California water system to continue to provide water at historical levels, largely because warming makes it more difficult to store precipitation as snow. When precipitation falls as rain or when the snowmelt is early, California loses up to a third of its water storage capacity.

The second unusual challenge for California agriculture is that most of the major crops are perennial plants. Crops like grapes, oranges, nuts, and avacados all come from plants that live for many years and often do not reach maximum production for several years. When perennial plants are damaged by a weather extreme, the losses typically go well beyond the price for replacement plants. Often, the real price is the delay in getting back to market.

In California, the historic risks to climate-related crop production have come from lack of water for irrigation but also from flooding, high temperatures, and low temperatures. One well documented example of temperature sensitivity concerns the fact that cherry trees require a chilling period to set fruit, and many traditional cherry areas are now becoming too warm for consistent cherry production.

Tourism is also vulnerable to climate change. One of the most vulnerable activities is skiing. California ski areas tend to be delightfully warm during the winter months, but this means that temperatures are not much below freezing. Ski areas around the country, including California are discovering that they need to make changes in opening or closing dates and in the operation of low-elevation runs. Golf is another example of a climate sensitive sport, mainly because courses require large amounts of water, year-round. Variability in precipitation and water availability are major banes of golfing. Other aspects of tourism with the potential to be climate sensitive include tourism related to agriculture (especially wine production) and summer access to fire prone areas. In the area of ag-tourism, the big issue is variability in water supply. In fire prone areas (including most of the forested are in the US), a relatively small change in fire frequency can result in a large change in suitability for agriculture.

3) What influence is climate change expected to have on the frequency of extreme events? Can you please discuss the trend in record high temperatures in the U.S. and whether this trend is consistent with climate change?

Based on the announcement made January 8 by NOAA, 2012 was the hottest year on record in the contiguous US. It was hotter than the previous record, 1998, by about 1 degree and hotter than the 20th century average by 3.2 degrees. Weather stations in the US recorded 34,007 record highs in 2012 but only 6407 record lows. In 2012, the US experienced 11 disasters with economic losses exceeding $1 billion. These ranged from horrifying wildfires in Colorado, to intense drought in the Midwest, to hurricane Sandy in the East. Washington DC experienced a fierce "Derecho". Many of these events are examples of the kinds of events that are likely to become more frequent or more damaging as a result of climate change. The link between warming and heat waves is clear, as is the link between warming and wildfires. Data on the link between warming and drought is still incomplete, but some regions are already experiencing more sever or long-lasting droughts. We still don't know if warming will influence the frequency or severity of hurricanes and other storms, but sea-level rise is already amplifying damages related to storm surge.

Senator BOXER. Thank you, Dr. Field.

Now, I understand—Senator Sessions, would you like to introduce the minority witness, John Christy, Dr. Christy?

Senator SESSIONS. I would be honored if you would allow me to do that.

Senator BOXER. I would love for you to do that. Sure.

Senator SESSIONS. Dr. Christy is a Distinguished Professor of Atmospheric Science, I believe the only climatologist here today. Since 1987 he has been a professor at the Atmospheric Science Department at the University of Alabama, Huntsville. He currently serves as Director of the Earth Science System Center. He holds Master and Doctorate degrees in Atmospheric Sciences from the University of Illinois and in mathematics and a Master of Divinity.

He has served as Alabama State Climatologist since 2000. During his time, he was worked with Dr. Roy Spencer to produce a global temperature data set from satellite observation. For their work, Drs. Christy and Spencer were awarded NASA's prestigious Medal for Exceptional Scientific Achievement in 1991. Five years later he and Dr. Spencer were recognized by the American Meteorological Society for the development of a precise record of global temperatures from operational polar orbiting satellite data.

For his contribution to climatology and research, he was inducted as a Fellow into the American Meteorological Society in 2002. He has been involved with the Intergovernmental Panel on Climate Change by serving as a contributor and lead author on U.N. reports. Through his efforts working with the IPCC, satellite temperature became classified as high quality data sets for the purpose of climatology research.

He served on five different national research council panels and committees, participated in research projects funded by NASA, NOAA, DOE, and DOT and the State of Alabama, published numerous times in journals including Science and Nature, Journal of the Climate, and Journal of Geophysical Research. He has spent time in Africa. He is married with children and is no stranger to Washington. He has testified over a dozen times at the House and the Senate.

Thank you, Madam Chair.

Senator BOXER. Thank you so much. And I reserve the right to extend and revise my introductions to include the life stories, the awards, and the great speeches of our two witnesses.

[Laughter.]

Senator BOXER. But you could not have done a better job.

Dr. Christy, go ahead.

STATEMENT OF JOHN R. CHRISTY, PH.D., DISTINGUISHED PROFESSOR, DIRECTOR OF THE EARTH SYSTEM SCIENCE CENTER, DEPARTMENT OF ATMOSPHERIC SCIENCE, UNIVERSITY OF ALABAMA IN HUNTSVILLE

Mr. CHRISTY. Thank you, Chairman Boxer, Ranking Member Inhofe, and Senator Sessions and Committee members.

I am a climate scientist. I build data sets from scratch to answer questions about climate variability and to test assertions people make about climate change. And that really is what the scientific method is all about.

During the heat wave of late June and early July, high temperature extremes were becoming newsworthy. Claims were made that thousands of records were broken each day, and that is what global warming looks like. And that got a lot of attention.

However, these headlines were not based on climate science. As shown in Figure 1.3 of my testimony, which did not make it here today, it is scientifically more accurate to say this is what Mother Nature looks like because events even worse than these that we have seen here have happened in the past before greenhouse gases were increasing like they are today.

Now, it gives some people great comfort to offer a quick and easy answer when weather strays from the average rather than struggle with what the real truth is. The real truth is we do not know enough about the climate to even predict events like this.

Climatologists looking at the heat wave would not be alarmed because the number of daily high temperature records set in the most recent decade was only—were actually less than half of that set in the 1930s, as shown in my written testimony.

Senator SESSIONS. Would you like to use this chart that I had?

Mr. CHRISTY. No, it is a different chart. It is a different chart. But thank you, Senator. It is a different chart. More dramatic, I think, but I did not make it up.

I suppose most people forget that Oklahoma set a new record low of 31 below; it was not 27, it was 31 below this past year. And in the past 2 years, towns from Alaska to my home State of California established records for snowfall.

The recent anomalous weather cannot be blamed on carbon dioxide. More evidence is available now to suggest that the climate is not as sensitive to extra greenhouse gases as previously thought, and now I will put that second one there. This is a spaghetti chart. There are 34 climate models on there.

But if you just focus on the black line that Senator Sessions showed earlier, that is what the models indicate should be happening now. And yet the real world, where the circles are, you see it at the bottom, is what has actually happened.

The temperature of the models clearly has overdone what has happened, and when considering legislation I would encourage you to base it on the observations rather than the speculative trends of climate models. And basing legislation on observations means addressing the large year to year variations that were talked about, like droughts and flood that caused so much economic distress.

There is still a discrepancy between the warming and the traditional surface data sets and less warming in the atmosphere. A new study led by my colleague, UA Huntsville's Richard McNider, along with my observational studies, explains part of the reason for the difference. When the surface and air around a thermometer station are disturbed by, say, urbanization, farming, aerosols, and so on, nighttime surface temperatures will appear to be warm due to a complicated turbulent process, not the greenhouse effect. The bottom line is that traditional surface temperature is contaminated by such effects and is not an accurate indicator of greenhouse warming.

When it comes to legislation or regulatory actions, there really is nothing that will definitively alter whatever the climate is going to do. However, I suspect there will be some discernible economic consequences if energy costs rise.

As more CO_2 is released back into the atmosphere, there are benefits that are often overlooked. Most notable of these is the invigoration of plant life on which we and the rest of the animal world depend for food. CO_2 is fundamentally plant food, and therefore, our food.

Today, carbon energy provides about 87 percent of the world's energy demand. So, if CO_2 is increasing, that is an indicator that a nation is providing energy for its people who then live longer, healthier, and more productive lives. As someone who has lived in Africa, I can say that energy—without energy, life is brutal and short. So this is a goal of poor countries, to access energy.

I will close with this unpleasant thought. Demanding a reduction in worldwide CO_2 emissions without affordable, reliable alternatives means reducing the hope for prosperity of our fellow world citizens who are struggling to escape their impoverished condition.

Thank you for your time. I will be happy to answer questions that you may have.

[The prepared statement of Mr. Christy follows:]

John R. Christy, PhD
Alabama State Climatologist
The University of Alabama in Huntsville
Senate Environment and Public Works Committee
1 August 2012
One Page Summary

1. It is popular again to claim that extreme events, such as the current central U.S. drought, are evidence of human-caused climate change. Actually, the Earth is very large, the weather is very dynamic, and extreme events will continue to occur somewhere, every year, naturally. The recent "extremes" were exceeded in previous decades.

2. The average warming rate of 34 CMIP5 IPCC models is greater than observations, suggesting models are too sensitive to CO2. Policy based on observations, where year-to-year variations cause the most harm, will likely be far more effective than policies based on speculative model output, no matter what the future climate does.

3. New discoveries explain part of the warming found in traditional surface temperature datasets. This partial warming is unrelated to the accumulation of heat due to the extra greenhouse gases, but related to human development around the thermometer stations. This means traditional surface datasets are limited as proxies for greenhouse warming.

4. Widely publicized consensus reports by "thousands" of scientists are misrepresentative of climate science, containing overstated confidence in their assertions of high climate sensitivity. They rarely represent the range of scientific opinion that attends our relatively murky field of climate research. Funding resources are recommended for "Red Teams" of credentialed, independent investigators, who already study low climate sensitivity and the role of natural variability. Policymakers need to be aware of the full range of scientific views, especially when it appears that one-sided-science is the basis for promoting significant increases to the cost of energy for the citizens.

5. Atmospheric CO2 is food for plants which means it is food for people and animals. More CO2 generally means more food for all. Today, affordable carbon-based energy is a key component for lifting people out of crippling poverty. Rising CO2 emissions are, therefore, one indication of poverty-reduction which gives hope for those now living in a marginal existence without basic needs brought by electrification, transportation and industry. Additionally, modern, carbon-based energy reduces the need for deforestation and alleviates other environmental problems such as water and air pollution. Until affordable energy is developed from non-carbon sources, the world will continue to use carbon as the main energy source as it does today.

Written Statement of John R. Christy
The University of Alabama in Huntsville
Committee on Environment and Public Works
1 August 2012

I am John R. Christy, Distinguished Professor of Atmospheric Science, Alabama's State Climatologist and Director of the Earth System Science Center at The University of Alabama in Huntsville. I have served as a Lead Author and Contributing Author of IPCC assessments, have been awarded NASA's Medal for Exceptional Scientific Achievement and in 2002 elected a Fellow of the American Meteorological Society.

It is a privilege for me to offer my views of climate change based on my experience as a climate scientist. My research area might be best described as building datasets from scratch to advance our understanding of what the climate is doing and why. This often involves weeks and months of tedious examination of paper records and then digitizing the data for use in computational analysis. I have used traditional surface observations as well as measurements from balloons and satellites to document the climate story. Many of my datasets are used to test hypotheses of climate variability and change. In the following I will address five issues that are part of the discussion of climate change today, some of which will be assisted by the datasets I have built and published.

1. EXTREME EVENTS

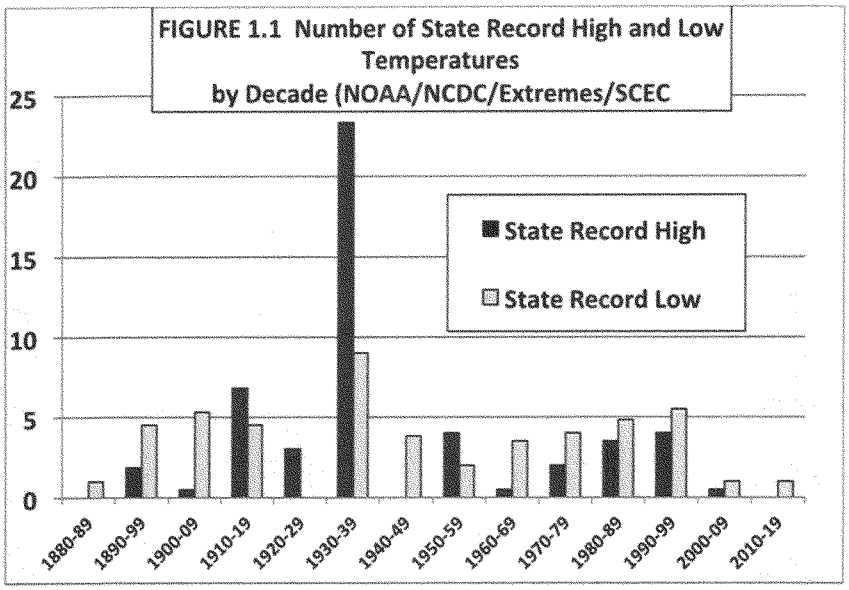
Recently it has become popular to try and attribute certain extreme events to human causation. The Earth however, is very large, the weather is very dynamic, especially at local scales, so that extreme events of one type or another will occur somewhere on the planet in every year. Since there are innumerable ways to define an extreme event (i.e. record high/low temperatures, number of days of a certain quantity, precipitation total over 1, 2, 10 ... days, snowfall amounts, etc.) this essentially assures us that there will be numerous "extreme events" in every year because every year has unique weather patterns. The following assesses some of the recent "extreme events" and demonstrates why they are poor proxies for making claims about human causation.

Midwestern Drought

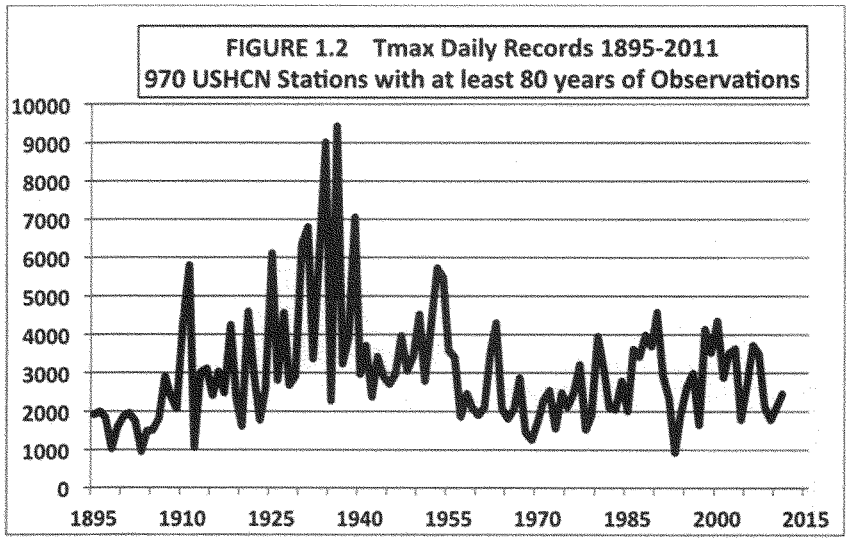
To put it simply, Andreadis and Lettenmaier (2006) found that for the Midwest, "Droughts have, for the most part, become shorter, less frequent, less severe, and cover a smaller portion of the country over the last century." In other words, droughts have always happened in the Midwest and they are not getting worse (more on Midwest heat waves below and on Midwest drought in Section 2).

Extreme High and Low Temperatures

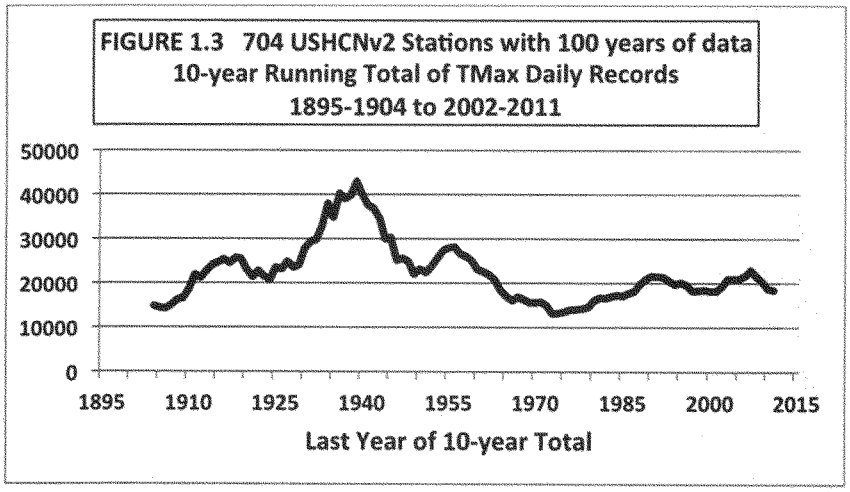
Another extreme metric is the all time record high temperature for each state. The occurrence of the records by decade (Figure 1.1 below) makes it obvious that the 1930s were the most extreme decade and that since 1960, there have been more all-time cold records set than hot records in each decade.



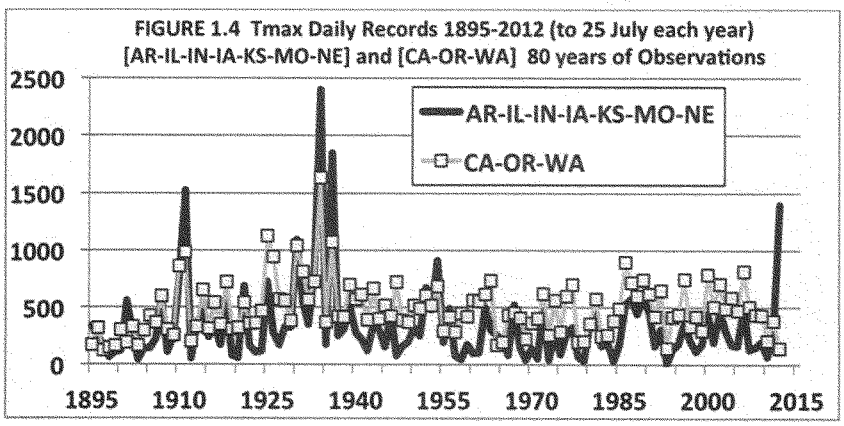
However, there are only 50 states, and this is a number that isn't large enough to give the best statistical results. Below are the year-by-year numbers of *daily* all-time record high temperatures from a set of 970 weather stations with at least 80 years of record (NOAA/NCDC/USHCNv2). There are 365 opportunities in each year (366 in leap years) for each of the 970 stations to set a record high (TMax). These have been added up by years and displayed in the Fig. 1.2 below. Note the several years above 6000 events prior to 1940 and none above 5000 since 1954. The clear evidence is that extreme high temperatures are not increasing in frequency, but actually appear to be decreasing. The recent claims about thousands of new record high temperatures were based on stations whose length-of-record could begin as recently as 1981, thus missing the many heat waves of the 20th century. Thus, any moderately hot day now will be publicized as setting records for these young stations because they were not operating in the 1930s. The figure below gives what a climatologist would want to know because it uses only stations with long records.



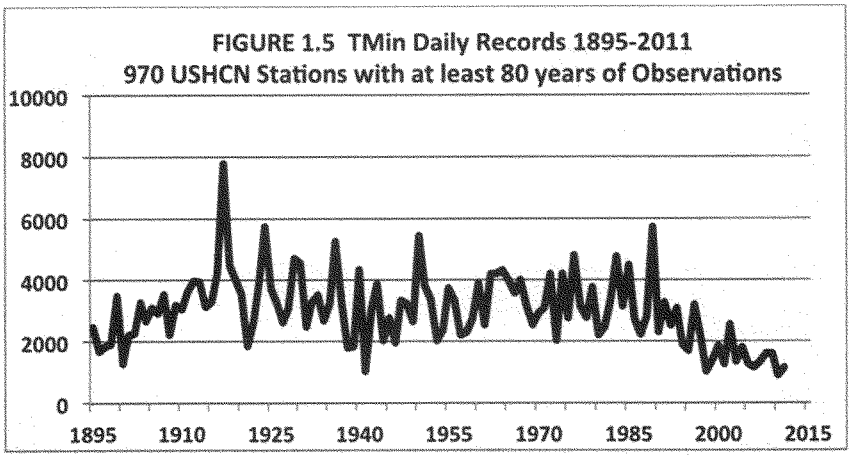
The somewhat ragged line above is more meaningful for climate purposes if we take the total record highs for ten-year periods, year-by-year, i.e. 1895-1904, 1896-1905, … 2002-2011. In Figure 1.3 below the record daily highs for 704 stations which have at least 100 years of data are plotted. Note that the value for the most recent decade is less than half of what was observed in the 1930s.



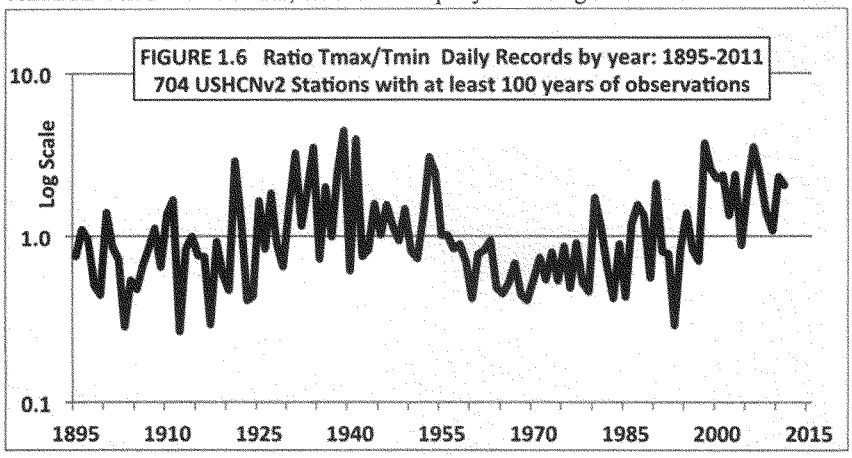
To include the heat wave of 2012 in this discussion, I have calculated the number of record high temperatures (Fig. 1.4) for stations in 7 central-US states where the heat is worst (AR-IL-IN-IA-MO-NE) and stations on the West Coast (CA-OR-WA). The groupings have about the same number of stations and all years show results beginning in January and ending on 25 July of each year. Notice that the Central-US and West Coast both felt the heat waves of 1911 and the 1930s when the highest number of events occurred for both regions. However, the current 2012 event shows high numbers in the Central-US, but a dearth of record highs along the West Coast, indicating the extent of the heat wave is smaller than previous events. (Note the values for 2012 have been increased by 15 percent to account for a few missing stations.)



A different picture emerges for the record cold temperatures for 970 US stations (TMin, Figure 1.5). Here we see a more even distribution up through the 1980's with a fairly noticeable drop-off in record low temperatures over the past 25 years. The cause for this drop-off is discussed in Section 3 of this testimony.



An interesting result is produced by taking the ratio year-by-year of the number of TMax daily records divided by the number of TMin daily records (Figure 1.6 below). The two large periods of more record highs than lows are in the 1930s and the last 15 years. The first high-ratio period in the 1930s was due to numerous TMax records while the more recent period was due to fewer TMin records. This decline in the record low temperatures (TMin) in the past 25 years is likely related to the general disturbance by human development around the thermometer stations (again, discussed in Section 3). Meehl et al., 2009 did a similar analysis, but started later, in 1950. This led to the claim of a rapidly rising ratio of record highs to record lows. Had the authors gone back only two more decades to look at a more complete climate record, and had taken into account the contamination of TMin values, the claim of rapidly increasing ratios would not hold.



Texas Drought of 2011

A recent claim that the 2011 drought in Texas was 20 times more likely due to extra greenhouse gases was based on statistics from a modeling exercise (http://www.noaanews.noaa.gov/stories2012/20120710_stateoftheclimatereport.html.) As it turns out, the model overstated the warming rate of Texas, so that it's statistics wouldn't apply correctly to the real world. In fact, the authors of the original article actually made that point in their study saying the result gave very limited information regarding real world impacts, and that the amount of impact of greenhouse gases was unknown. See http://cliffmass.blogspot.com/2012/07/texas-tall-tales-and-global-warming.html and http://blog.chron.com/climateabyss/2012/07/twenty-times-more-likely-not-the-science/ for more explanation. This was (another) unfortunate episode in misrepresenting the science of climatology.

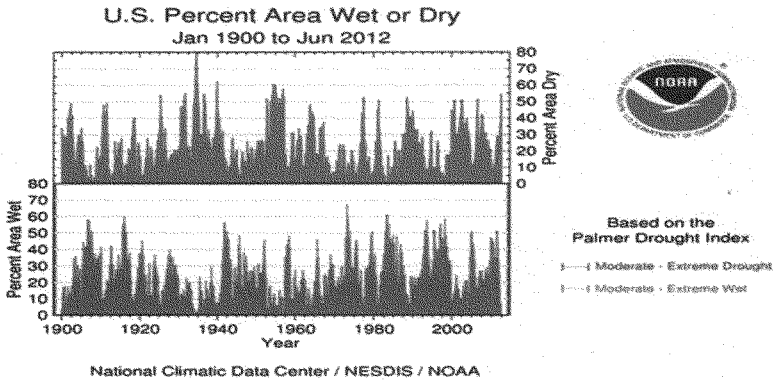
Colorado Fires

Colorado has been in the news this year due to a number of serious wildfires. These fires are usually caused by humans and problematic to study from a climate standpoint because of fire suppression activities that have been around since the turn of the 20th century. Whereas there were many low-intensity fires before these efforts began, now there tend to be fewer but more intense fires due to the buildup of fuel. Western fires in the past have covered much more ground than the tragic fires we see today (e.g. 1910 over 3 million acres). In any case, droughts are related to weather patterns that become stationary, so it is useful to ask the question: have weather patterns shown a tendency to become more stationary, thus creating the opportunity for long dry/hot or wet/cool spells? (Note that the current heat in the Plains is one half of the pattern, the cooler-than-normal West Coast/Alaska is the other.)

A project which seeks to generate consistent and systematic weather maps back to 1871 (20th Century Reanalyisis Project, http://www.esrl.noaa.gov/psd/data/20thC_Rean/) has taken a look at the three major indices which are often related to extreme events. As Dr. Gill Campo of the University of Colorado, leader of the study, noted to the *Wall Street Journal* (10 Feb 2011) "… we were surprised that none of the three major indices of climate variability that we used show a trend of increased circulation going back to 1871." (The three indices were the Pacific Walker Circulation, the North Atlantic Oscillation and the Pacific-North America Oscillation, Compo et al. 2011.) In other words, there appears to be no supporting evidence over this period that human factors have influenced the major circulation patterns which drive the larger-scale extreme events. Again we point to natural, unforced variability (i.e. Mother Nature) as the dominant feature of events that have transpired in the past 130 years.

U.S. Drought

Though the conterminous U.S. covers only 1.8 percent of the globe, there are good records for many weather variables. Below is the month-by-month percentage of the area that is classified as moderate to extreme for dryness and wetness from NOAA. As can be seen below there is a tremendous amount of variability (near zero to near 80 percent), but no long-term trend.



Recent snowfall in the United States

Snowfall reached record levels in 2009-10 and 2010-11 in some eastern US locations and also in a few western locations in 2010-11. NOAA's Climate Scene Investigators committee issued the following statement regarding this, indicating, again, that natural, unforced variability (again, Mother Nature) explains the events.

> *Specifically, they wanted to know if human-induced global warming could have caused the snowstorms due to the fact that a warmer atmosphere holds more water vapor. The CSI Team's analysis indicates that's not likely. They found no evidence — no human "fingerprints" — to implicate our involvement in the snowstorms. If global warming was the culprit, the team would have expected to find a gradual increase in heavy snowstorms in the mid-Atlantic region as temperatures rose during the past century. But historical analysis revealed no such increase in snowfall.*

In some of my own studies I have looked closely at the snowfall records of the Sierra Nevada mountains of California from the earliest records from the Southern Pacific Railroad beginning in 1878. Long-term trends in snowfall (and thus water resources) in

this part of California are essentially zero, indicating no change in this valuable resource to the state (Christy and Hnilo, 2010, Christy 2012.)

From the broad perspective, where we consider all the extremes above, we should see a warning – that the climate system has always had within itself the capability of causing devastating events and these will certainly continue with or without human influence on the climate. Thus, societies should plan for infrastructure projects to withstand the worst that we already know has occurred, and to recognize, in such a dynamical system, that even worse events *should* be expected. In other words, the set of the *measured* extreme events of the small climate history we have, since about 1880, does *not* represent the full range of extreme events that the climate system (i.e. Mother Nature) can actually generate. The most recent 130 years is simply our current era's small sample of the long history of climate.

There will certainly be events in this coming century that exceed the magnitude of extremes measured in the past 130 years in many locations. To put it another way, a large percentage of the worst extremes over the period 1880 to 2100 will occur after 2011 simply by statistical probability without any appeal to human forcing at all. Records are made to be broken. Going further, one would assume that about 10 percent of the record extremes that occur over a thousand-year period ending in 2100 should occur in the 21st century. Are we prepared to deal with events even worse than we've seen so far? Spending which is directed to creating resiliency to these sure-to-come extremes, particularly drought/flood extremes, seems rather prudent to me – since there are no human means to make them go away regardless of what some regulators might believe.

Looking at the longer record of climate patterns

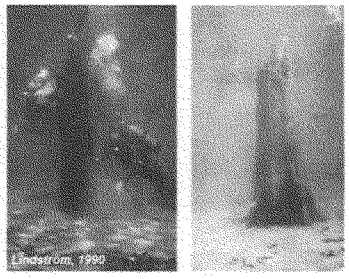
Climatologists realize that the period of time over which we have had instruments to measure the climate (~130 years) is very brief compared to the history of the current 10,000-year interglacial period. Taking a look at the larger picture shows the capability of Mother Nature to produce extreme situations.

Megadroughts of the past 1000+ years

There are several types of records from the flora and fauna of the past 1000 years that provide evidence that droughts of extreme duration (decades) occurred in our nation, primarily in the Great Plains westward to the Pacific Coast.

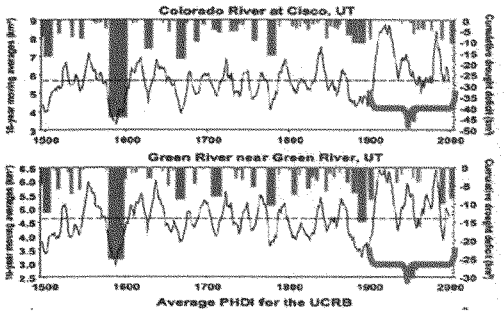
California

At right are photos from Lindstrom (1990) in which trees grew on dry ground around 900 years ago in what is now a Sierra Nevada alpine lake. This indicates that a drastic but natural change to a much drier climate must have lasted for at least a century for trees to have grown to these sizes on dry ground.



Rocky Mountains

A 500-year history of moisture in the upper Colorado River basin (below) indicates the past century was quite moist while major multi-decadal droughts occurred in all four prior centuries (Piechota et al. 2004.) Indeed, the conclusion of Piechota et al. states that after examining the paleo-record, the present-day droughts "could be worse." These and other evidences point to the real probability that water supply in the West will see declines simply as a matter of the natural variability of climate.



Great Plains

In the Great Plains, the period from 3000 to 1500 years ago saw a drier and warmer climate during which a significant parabolic sand dune ecosystem developed, especially in western Nebraska and NE Colorado (Muhs 1985). In other words, the Great Plains resembled a desert. Many of these areas experienced dune "reactivation" during Medieval times (900-1300 AD). Then, the climate moistened and cooled beginning around 1300 AD to support the short-grass prairie seen today, though "reactivation" is possible at any time (Schmeisser, 2009). Indeed, Muhs and Holliday (1995) found that dune reactivation can occur within decadal time scales from extended drought by examining the Great Plains environment of only the past 150 years.

With the massive use of ground water for irrigation, the High Plains Aquifer has declined an average of 12.8 ft, with some areas in the Texas panhandle down over 150 ft. The key point here is that the Plains is subject to natural (and sobering) long-term droughts that would very likely tax the current water management system (ground-water

withdrawals) while not replenishing the aquifer, producing a situation of reduced agricultural productivity, especially in its southern reaches.

A sample study of why extreme events are poor metrics for global changes

In the examples above, we don't see increases in extreme events (which is also true for tornadoes, hurricanes, floods, etc. - see my House testimony of 31 March 2011) but we must certainly be ready for more to come as part of nature's variability. I want to illustrate how one might use extreme events to conclude (improperly I believe) that the weather in the USA is becoming less extreme and/or colder.

Going back to Fig. 1.1 (the number of all-time state records) we see the following. About 75 percent of the states recorded their hottest temperature prior to 1955, and, over 50 percent of the states experienced their record cold temperatures after 1940. Overall, only a third of the records (hot or cold) have been set in the second half of the whole period. One could conclude, if they were so inclined, that the climate of the US is becoming less extreme because the occurrence of state extremes of hot and cold has diminished dramatically since 1955. Since 100 of anything appears to be a fairly large sample (2 values for each of 50 states), this on the surface seems a reasonable conclusion.

Then, one might look at the more recent record of extremes and learn that no state has achieved a record high temperature in the last 15 years (though one state has tied theirs.) However, five states have observed their all-time record low temperature in these past 15 years plus one tie. This includes last year's record low of 31°F below zero in Oklahoma, breaking their previous record by a rather remarkable 4°F. If one were so inclined, one could conclude that the weather that people worry about (extreme cold) is getting worse in the US. (Note: this lowering of absolute cold temperature records is nowhere forecast in climate model projections, nor is a significant drop in the occurrence of extreme high temperature records.)

I am not using these statistics to prove the weather in the US is becoming less extreme and/or colder. My point is that extreme events are poor metrics to use for detecting climate change. Indeed, because of their rarity (by definition) using extreme events to bolster a claim about any type of climate change (warming or cooling) runs the risk of setting up the classic "non-falsifiable hypothesis." For example, we were told by the IPCC that "milder winter temperatures will decrease heavy snowstorms" (TAR WG2, 15.2.4.1.2.4). After the winters of 2009-10 and 2010-11, we are told the opposite by advocates of the IPCC position, "Climate Change Makes Major Snowstorms More Likely" (http://www.ucsusa.org/news/press_release/climate-change-makes-snowstorms-more-likely-0506.html).

The non-falsifiable hypotheses can be stated this way, "whatever happens is consistent with my hypothesis." In other words, there is no event that would "falsify" the hypothesis. As such, these assertions cannot be considered science or in anyway informative since the hypothesis' fundamental prediction is "anything may happen." In the example above if winters become milder or they become snowier, the non-falsifiable hypothesis stands. This is not science.

As noted above, there are innumerable types of events that can be defined as extreme events – so for the enterprising individual (unencumbered by the scientific method), weather statistics can supply an unlimited, target-rich environment in which to discover a "useful" extreme event. It's like looking at all of the baseball games in history to calculate an extreme event. Since every game is unique in some way, that uniqueness can be asserted to be an extreme (i.e. number of consecutive alternating strikes and balls, number of fouls from left-handed batters thrown by left-handed pitchers, number of players in third inning with last name starting with "R", etc.)

Thus, when the enterprising individual observes an unusual weather event, it may be tempting to define it as a once-for-all extreme metric to "prove" a point about climate change – even if the event was measured at a station with only 30 years of record. This works both ways with extremes. If one were prescient enough to have predicted in 1996 that over the next 15 years, five states would break all-time record cold temperatures while none would break record high temperatures as evidence for cooling, would that prove CO2 emissions have no impact on climate? No. Extreme events happen, and their causes are intricately tied to the semi-unstable dynamical situations that can occur out of an environment of natural, unforced variability.

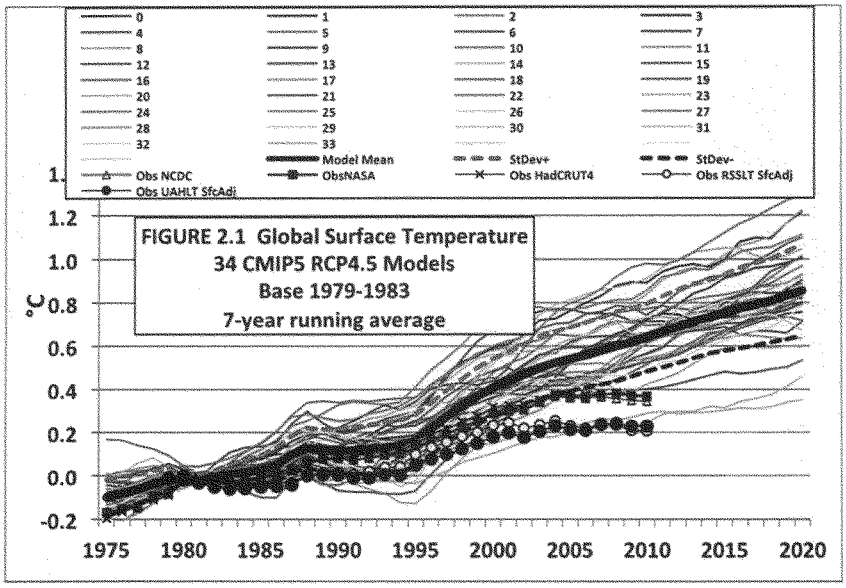
Science checks hypotheses (assertions) by testing specific, falsifiable predictions implied by those hypotheses. The predictions are to be made in a manner that, as much as possible, is blind to the data against which they are evaluated. It is the testable predictions from hypotheses, derived from climate model output, that run into trouble as shown in Section 2. Before going on to that test, the main point here is that extreme events do not lend themselves as being rigorous metrics for *convicting* human CO2 emissions of being guilty of causing them.

2. RECENT CLIMATE MODEL SIMULATIONS

One of the key questions policymakers ask is what will happen with the Earth's weather in the decades to come. More importantly, they want to know how things might change specifically for their constituents. One pathway to follow is to examine the output of

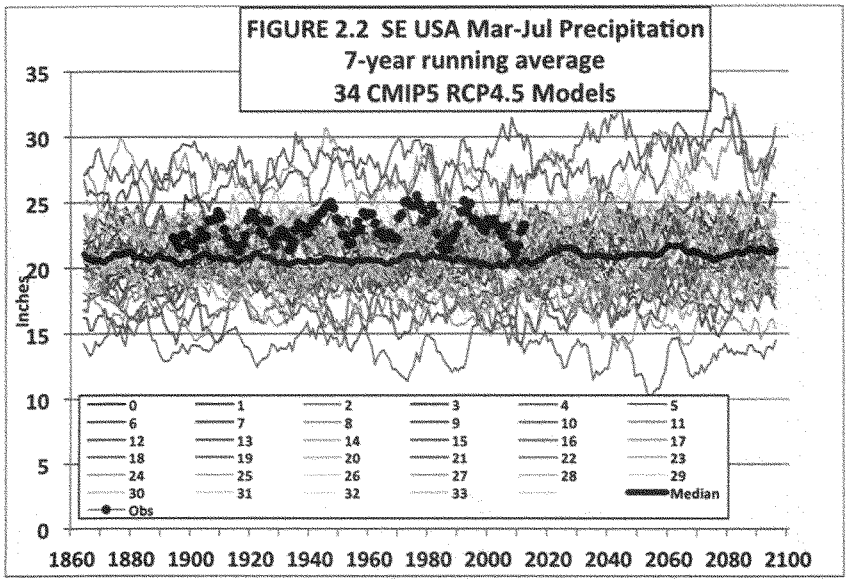
climate models that seek to predict likely outcomes. If one has a lot of confidence in the model projections that terrible weather is on the horizon, then it is tempting to devise policy that the same models say would indicate would somehow mitigate that problem.

In Figure 2.1 below, I display the results from 34 of the latest climate model simulations of global temperature that will be used in the upcoming IPCC AR5 assessment on climate change (KNMI Climate Explorer). All of the data are given a reference of 1979-1983, i.e. the same starting line. Along with these individual model runs I show their average (thick black line) and the results from observations (symbols). The two satellite-based results (circles, UAH and RSS) have been proportionally adjusted so they represent surface variations for an apples-to-apples comparison. The evidence indicates the models on average are over-warming the planet by quite a bit, implying there should be little confidence that the models can answer the question asked by policymakers. Basing policy on the circles (i.e. real data) seems more prudent than basing policy on the thick line of model output. Policies based on the circles would include adaptation to extreme events that will happen because they've happened before (noted above and below) and since the underlying trend is relatively small.



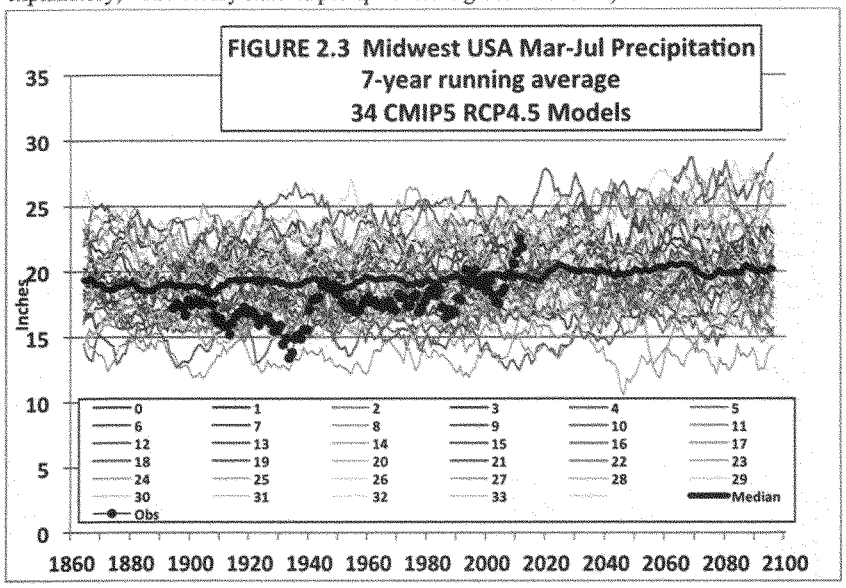
A more specific question for those of us in the Southeast is what might happen to our growing season rainfall – a key variable for our economy. Figure 2.2 below shows what

these 34 models depict for March to July rainfall (7-year running averages) with the circles being the observations. It's apparent first of all that the models are generally too dry. Secondly, there really is no information for policy here. The trend in the average of the models is so close to zero as to be uninformative (+0.8 inches/century for 1980 - 2100) with results varying from 3.7 inches/century wetter to 1.6 inches/century drier. Neither one of these rates is important because the year-to-year variations in rainfall from observations show a range from 14.9 to 30.7 inches. It is apparent that for a critical quantity such as precipitation, one cannot have confidence in model projections, nor in their attempts to demonstrate what might happen with control strategies for carbon dioxide. Again, an examination of the historical record of rainfall (circles) gives considerable information on what might be expected in terms of the variability, and thus a pathway to plan to accommodate the droughts and floods that are sure to come since they've happened in the past.



A similar exercise was done for the Midwest region (100W-85W, 37.5N-45N) since it is in the news in Figure 2.3 below. The character of the observed precipitation shows a clear rise in total amount through the years. However, the same comments regarding the model results for the Southeast apply for the Midwest too as the models indicate an average trend (1980-2100) of a tiny +0.9 inches/century but which really comes down to a shift around 2020 with steady values thereon. The natural range for this region from history varies wildly from 8.7 to 26.7 inches from one growing season to the next. Once

again, policies which deal with the large year-to-year variations which cause the most problems for the economy would address a real threat that will continue to occur regardless of the human effects on climate change. The model output provides no information for substantive policy (see also Stephens et al. 2010 whose title is self explanatory, "The dreary state of precipitation in global models.")



3. NEW INFORMATION ON SURFACE TEMPERATURE PROCESSES

In general, the issue of global warming is dominated by considering the near-surface air temperature (Tsfc) as if it were a standard by which one might measure the climate impact of the extra warming due to increases in greenhouse gases. Fundamentally, the proper variable to measure is heat content, or the amount of heat energy (measured in joules) in the climate system, mainly in the oceans and atmosphere. Thus the basic measurement for detecting greenhouse warming is how many more joules of energy are accumulating in the climate system over that which would have occurred naturally. This is a truly "wicked" problem (see House Testimony, Dr. Judith Curry, 17 Nov 2010) because we do not know how much accumulation can occur naturally.

Unfortunately, discussions about global warming focus on Tsfc even though it is affected by many more processes than the accumulation of heat in the climate system. Much has been documented on the problems, and is largely focused on changes in the local

environment, i.e. buildings, asphalt, etc. This means that using Tsfc, as measured today, as a proxy for heat content (the real greenhouse variable) can lead to an overstatement of greenhouse warming if the two are assumed to be too closely related.

A new paper by my UAHuntsville colleague Dr. Richard McNider (McNider et al. 2012) looked at reasons for the fact daytime high temperatures (TMax) are really not warming much while nighttime low temperatures (TMin) show significant warming. This has been known for some time and found in several locations around the world (e.g. California - Christy et al. 2006, East Africa – Christy et al. 2009, Uganda – just released data). Without going into much detail, the bottom line of the study is that as humans disturb the surface (cities, farming, deforestation, etc.) this disrupts the normal formation of the shallow, surface layer of cooler air during the night when TMin is measured. In a complicated process, due to these local changes, there is greater mixing of the naturally warmer air above down to the shallow nighttime cool layer. This makes TMin warmer, giving the appearance of warmer nights over time. The subtle consequence of this phenomenon is that TMin temperatures will show warming, but this warming is from a turbulent process which redistributes heat near the surface not to the accumulation of heat related to greenhouse warming of the deep atmosphere. The importance of this is that many of the positive feedbacks that amplify the CO2 effect in climate models depend on warming of the deep atmosphere not the shallow nighttime layer.

During the day, the sun generally heats up the surface, and so air is mixed through a deep layer. Thus, the daily high temperature (TMax) is a better proxy of the heat content of the deep atmosphere since that air is being mixed more thoroughly down to where the thermometer station is. The relative lack of warming in TMax is an indication that the rate of warming due to the greenhouse effect is smaller than models project (Section 2).

The problem with the popular surface temperature datasets is they use the average of the daytime high and nighttime low as their measurement (i.e. (TMax+TMin)/2). But if TMin is not representative of the greenhouse effect, then the use of TMin with TMax will be a misleading indicator of the greenhouse effect. TMax should be viewed as a more reliable proxy for the heat content of the atmosphere and thus a better indicator of the enhanced greenhouse effect. This exposes a double problem with models. First of all, they overwarm their surface compared with the popular surface datasets (the non-circle symbols in Fig. 2.1). Secondly, the popular surface datasets are likely warming too much to begin with. This is why I include the global satellite datasets of temperature which are not affected by these surface problems and more directly represent the heat content of the atmosphere (see Christy et al. 2010, Klotzbach et al. 2010).

Fall et al. 2011 found evidence for spurious surface temperature warming in certain US stations which were selected by NOAA for their assumed high quality. Fall et al. categorized stations by an official system based on Leroy 1999 that attempted to determine the impact of encroaching civilization on the thermometer stations. The result was not completely clear-cut as Fall et al. showed that disturbance of the surface around a station was not a big problem, but it was a problem. A new manuscript by Muller et al. 2012, using the old categorizations of Fall et al., found roughly the same thing. Now, however, Leroy 2010 has revised the categorization technique to include more details of changes near the stations. This new categorization was applied to the US stations of Fall et al., and the results, led by Anthony Watts, are much clearer now. Muller et al. 2012 did not use the new categorizations. Watts et al. demonstrate that when humans alter the immediate landscape around the thermometer stations, there is a clear warming signal due simply to those alterations, especially at night. An even more worrisome result is that the adjustment procedure for one of the popular surface temperature datasets actually increases the temperature of the rural (i.e. best) stations to match and even exceed the more urbanized (i.e. poor) stations. This is a case where it appears the adjustment process took the spurious warming of the poorer stations and spread it throughout the entire set of stations and even magnified it. This is ongoing research and bears watching as other factors as still under investigation, such as changes in the time-of-day readings were taken, but at this point it helps explain why the surface measurements appear to be warming more than the deep atmosphere (where the greenhouse effect should appear.)

4. CONSENSUS SCIENCE

The term "consensus science" will often be appealed to regarding arguments about climate change to bolster an assertion. This is a form of "argument from authority." Consensus, however, is a political notion, not a scientific notion. As I testified to the Inter-Academy Council in June 2010, wrote in *Nature* that same year (Christy 2010), and documented in my written House Testimony last year (House Space, Science and Technology, 31 Mar 2011) the IPCC and other similar Assessments do not represent for me a consensus of much more than the consensus of those selected to agree with a particular consensus. The content of these climate reports is actually under the control of a relatively small number of individuals - I often refer to them as the "climate establishment" – who through the years, in my opinion, came to act as *gatekeepers* of scientific opinion and information, rather than *brokers*. The voices of those of us who object to various statements and emphases in these assessments are by-in-large dismissed rather than acknowledged. This establishment includes the same individuals who become the "experts" called on to promote IPCC claims in trickle-down fashion to government reports such as the endangerment finding by the Environmental Protection Agency. As outlined in my House Testimony, these "experts" become the authors and evaluators of

their own research relative to research which challenges their work. But with the luxury of having the "last word" as "expert" authors of the reports, alternative views vanish.

I've often stated that climate science is a "murky" science. We do not have laboratory methods of testing our hypotheses as many other sciences do. As a result what passes for science includes, opinion, arguments from authority, dramatic press releases, and fuzzy notions of consensus generated by a preselected group. This is not science.

I noticed the House passed an amendment last year to de-fund the U.N.'s Intergovernmental Panel on Climate Change (IPCC.) We know from Climategate emails and many other sources of information that the IPCC has had problems with those who take different positions on climate change than what the IPCC promotes. There is another way to deal with this however. Since the IPCC activity *is* funded by US taxpayers, then I propose that five to ten percent of the funds be allocated to a group of well-credentialed scientists to produce an assessment that expresses legitimate, alternative hypotheses that have been (in their view) marginalized, misrepresented or ignored in previous IPCC reports (and thus EPA and National Climate Assessments). Such activities are often called "Red Team" reports and are widely used in government and industry. Decisions regarding funding for "Red Teams" should not be placed in the hands of the current "establishment" but in panels populated by credentialed scientists who have experience in examining these issues. Some efforts along this line have arisen from the private sector (i.e. *The Non-governmental International Panel on Climate Change* at http://nipccreport.org/ and Michaels (2012) *ADDENDUM:Global Climate Change Impacts in the United States*). I believe policymakers, with the public's purse, should actively support the assembling all of the information that is vital to addressing this murky and wicked science, since the public will ultimately pay the cost of any legislation alleged to deal with climate.

Topics to be addressed in this "Red Team" assessment, for example, would include (a) evidence for a low climate sensitivity to increasing greenhouse gases, (b) the role and importance of natural, unforced variability, (c) a rigorous and independent evaluation of climate model output, (d) a thorough discussion of uncertainty, (e) a focus on metrics that most directly relate to the rate of accumulation of heat in the climate system (which, for example, the problematic surface temperature record does not represent well), (f) analysis of the many consequences, including benefits, that result from CO2 increases, and (g) the importance that affordable and accessible energy has to human health and welfare. What this proposal seeks to accomplish is to provide to the congress and other policymakers a parallel, scientifically-based assessment regarding the state of climate science which addresses issues which here-to-for have been un- or under-represented by previous tax-

payer funded, government-directed climate reports. In other words, our policymakers need to see the entire range of scientific findings regarding climate change.

5. IMPACT OF EMISSION CONTROL MEASURES

The evidence above suggests that climate models overestimate the response of temperature to greenhouse gas increases. Also shown was a lack of evidence to blame humans for an increase in extreme events. One cannot convict CO2 of causing any of these events, because they've happened in the past before CO2 levels rose. Even so, using these climate model simulations we can calculate that the theoretical impact of legislative actions being considered on the global temperature is essentially imperceptible (Christy JR, House Ways and Means Testimony, 25 Feb 2009). In such calculations we simply run the model with and without the proposed changes in greenhouse gases to see the difference in the models' climates. The result is that actions will not produce a measurable climate effect that can be attributable or predictable with any level of confidence, especially at the regional level.

When I testified before the Energy and Commerce Oversight and Investigations subcommittee in 2006 I provided information on an imaginary world in which 1,000 1.4 gW nuclear power plants would be built and operated by 2020. This, of course, will not happen. Even so, this Herculean effort would result in at most a 10 percent reduction in global CO2 emissions, and thus exert a tiny impact on whatever the climate is going to do. The results today are still the same. Indeed, with the most recent estimates of low climate sensitivity, the impact of these emission-control measures will be even tinier since the climate system doesn't seem to be very sensitive to CO2 emissions. The recent switch to natural gas represents a partial move to decarbonize our energy production since methane has four hydrogen atoms for every one carbon atom. Thus, there are now even less U.S. CO2 emissions to legislate away.

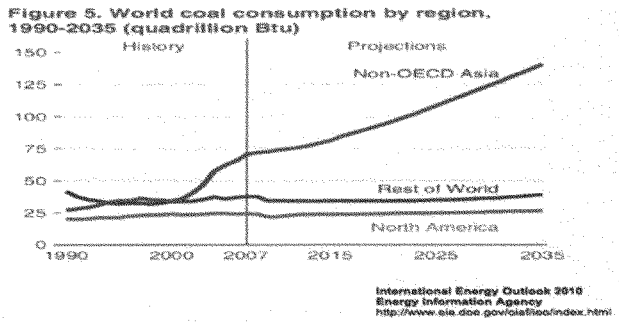
The Energy Information Administration lists 190 countries by CO2 emissions and Gross Domestic Product. This can be used to answer the question, how much in terms of goods and services does a country generate per ton of CO2 emissions? In terms of efficiency, the U.S. is ranked 81st near Australia (91st) and Canada (78th) two other geographically-large and well-advanced countries with considerable natural resources. China is 186th but France is 9th due to the fact over 80 percent of its electricity comes from nuclear power rather than carbon. A different way to look at this is to realize the U.S. produces 29 percent of the world's goods and emits only 18 percent of the world's CO2 emissions (EIA 2009 values.) In other words, the U.S. ranks rather well considering the energy intensive industries of farming, manufacturing, mining, metals processing, etc. that are performed here, the goods of which are sold to the world. So, we produce quite a bit

relative to our emissions – the kind of products and services that the world wants to buy. With the recent shift to more natural gas, the U.S. efficiency continues to rise. I suppose if one wanted to reduce U.S. emissions, one could legislate what the world should and should not buy. This, of course, is not a serious idea.

When thinking about policy regarding CO2, one cannot ignore the immense benefits produced directly by CO2 or indirectly from in its relationship to low-cost energy. It is a simple fact that CO2 is plant food and the world around us evolved when levels of CO2 were five to ten times what they are today. Our green world is a consequence of atmospheric CO2. And, food for plants means food for people. The extra CO2 we are putting into the atmosphere not only invigorates the biosphere, but also enhances the yields of our food crops. This is a tremendous benefit to nature and us in my view.

A rising CO2 concentration is also an indicator of human progress in health, welfare and security provided by affordable carbon-based energy. As someone who has lived in a developing country, I can assure the committee that without energy, life is brutal and short. At present, hundreds of millions of people are dependent on low-grade biomass (tree branches, dung, etc.) for energy. These sources place a huge burden, literally, on people to find, cut and carry the material where needed. Landscapes are deforested and waterways contaminated by these activities. And tragically, the U.N. estimates about 2 million children die each year due to diseases fostered by the toxic fumes produced when burning wood and dung in the homes. Higher density sources of fuel such as coal and natural gas utilized in centrally-produced power stations actually improve the environmental footprint of the poorest nations while at the same time lifting people from the scourge of poverty.

Coal use, which generates a major portion of CO2 emissions, will continue to rise as indicated by the Energy Information Administration's chart below. Developing countries in Asia already burn more than twice the coal that North America does, and that discrepancy will continue to expand. The fact our legislative actions will be inconsequential in the grand scheme of things can be seen by noting that these actions attempt to bend the blue curve for North American down a little, and that's all. So, downward adjustments to North American coal use will have virtually no effect on global CO2 emissions (or the climate), no matter how sensitive one thinks the climate system might be to the extra CO2 we are putting back into the atmosphere.



Thus, if the country deems it necessary to de-carbonize civilization's main energy sources, then *compelling* reasons beyond human-induced climate change need to be offered that must address, for example, ways to help poor countries develop affordable energy. Climate change alone is a weak leg on which to stand to justify a centrally-planned, massive change in energy production, infrastructure and cost.

Thank you for this opportunity to offer my views on climate change.

References

Andreadis, K.M. and D.P. Lettenmaier, 2006: Trends in 20th century drought over the continental United States. *Geophys. Res. Lett.*, 33, L10403, doi:10.1029/2006GL025711.

Christy, J.R., 2012: Searching for information in 133 years of California snowfall observations. *J. Hydro. Met.* DOI:10.1175/JHM-D-11-040.1.

Christy, J.R., B. Herman, R. Pielke, Sr., P. Klotzbach, R.T. McNider, J.J. Hnilo, R.W. Spencer, T. Chase and D. Douglass, 2010: What do observational datasets say about modeled tropospheric temperature trends since 1979? *Remote Sens.* 2, 2138-2169. Doi:10.3390/rs2092148.

Christy, J.R. and J.J. Hnilo, 2010: Changes in snowfall in the southern Sierra Nevada of California since 1916. *Energy & Env.*, **21**, 223-234.

Christy, J.R. 2010: Open Debate: Wikipedia Style, The IPCC, Cherish it, Tweak it, or Scrap it. *Nature*. 463, 730-732

Christy, J.R., W.B. Norris and R.T. McNider, 2009: Surface temperature variations in East Africa and possible causes. *J. Clim.* **22**, DOI: 10.1175/2008JCLI2726.1.

Christy, J.R., W.B. Norris, K. Redmond and K. Gallo, 2006: Methodology and results of calculating central California surface temperature trends: Evidence of human-induced climate change? *J. Climate*, **19**, 548-563.

Compo, G.P. et al. 2011. Review Article: The Twentieth Century Reanalysis Project. *Q. J. R. Meteorol. Soc.*, **137**, 1-28.

Fall, S., A. Watts, J. Nielsen-Gammon, E. Jones, D. Niyogi, J.R. Christy, and R.A. Pielke Sr., 2011: Analysis of the impacts of station exposure on the U.S. Historical Climatology Network temperatures and temperature trends. J. Geophys. Res., 116, D14120, doi:10.1029/2010JD015146.

Klotzbach, P.J., R.A.Pielke, Sr., R.A.Pielke, Jr., J.R. Christy, R.T. McNider. Correction to "An alternative explanation for differential temperature trends at the surface and in the lower troposphere." *J. Geophys. Res.* **2010**. Doi:10.1029/2009JD013655.

Leroy, M., 1999: Classification d'un site, Note Tech. 35, 12 pp. Dir. Des Syst. D'Obs., Meteo-France, Trappes, France.

Leroy, M., 2010: Siting Classification for Surface Observing Stations on Land, Climate, and Upper-air Observations *JMA/WMO Workshop on Quality Management in Surface*, Tokyo, Japan 27-30 July 2010

Lindstrom, Susan G. 1990. Submerged Tree Stumps as Indicators of Mid-Holocene Aridity in the Lake Tahoe Region. *Journal of California and Great Basin Anthropology*. 12(2):146-157.

McNider, R.T., G.J. Steeneveld, A.A.M. Holtslag, R.A.Pielke Sr., S. Mackaro, A. Pour-Biazar, J. Walters, U. Nair and J.R. Christy, 2012. Response and sensitivity of the nocturnal boundary layer over land to added longwave radiative forcing. *J. Geophys. Res.* in press.

Meehl, G.A., C. Tebaldi, G. Walton, D. Easterling, and L. McDaniel, 2009: The relative increase of record high maximum temperatures compared to record low minimum temperatures in the U.S. Geophys. Res. Lett.

Michaels, P., Editor, 2012: ADDENDUM: Global Climate Change Impacts in the United States. CATO Institute. 213 pp.

Muhs, D.R., 1985: Age and paleoclimatic significance of Holocene sand dunes in Northeastern Colorado. *Annals Assoc. Amer. Geographers*. 75, 566-582.

Muhs, D.R. and V.T. Holliday, 1995: Evidence of active dune sand on the Great Plains in the 19th century from accounts of early explorers. *Quaternary Res.*, 43, 198-208.

Muller, R.A., J. Wurtele, R. Rohde, R. Jackobsen, S. Permutter, A. Rosenfeld, J. Curry, D. Groom and C. Wickham, 2012: Earth atmospheric land surface temperature and station quality in the continuous United States. *J. Geophys. Res.*, submitted.

Piechota, T., J. Timilsena, G. Tottle and H. Hidalgo, 2004: The western U.S. drought, How bad is it? *EOS Transactions*, AGU, 85, 301-308.

Schmeisser, R.L., 2009: Reconstruction of paleoclimate conditions and times of the last dune reactivation in the Nebraska Sand Hills. University of Nebraska – Lincoln. Paper AAI3352250.

Stephens, G. et al. 2010: The dreary state of precipitation in global models. *J. Geophys. Res.*, **115**, doi:101029/1010JD014532.

Senator BOXER. Thank you so much, Dr. Christy.

Now we are going to turn to our last witness on this first panel, Dr. James McCarthy, Alexander Agassiz Professor of Biological Oceanography, Museum of Comparative Zoology, Harvard.

And we will expand your repertoire when we get to the written record.

STATEMENT OF JAMES J. MCCARTHY, PH.D., ALEXANDER AGASSIZ PROFESSOR OF BIOLOGICAL OCEANOGRAPHY, MUSEUM OF COMPARATIVE ZOOLOGY, HARVARD UNIVERSITY

Mr. MCCARTHY. Thank you, Chairman Boxer, Ranking Member Inhofe, and members of the Committee for your attention to the important matter of climate change.

I wish today to talk about new evidence that we see in the ocean for climate change and evidence of the ocean's response to the changing conditions in the atmosphere as we are increasing the insulation of the atmosphere with the addition of greenhouse gases.

The first figure that we will show on the easel is a checklist. It is a checklist that you might have imagined assembling in the 1960s when people were first saying, well, if greenhouse gases continue to increase, what would you expect to be the indicators in climate. This was published in 2009, a joint effort of NOAA and the American Meteorological Society.

If you could read those indicators, this is a figure that is contained in my written testimony, it is Figure 1 in the testimony as well; you would see that every indicator that you would expect to change, and the direction it would change the Earth through warming with the addition greenhouse gases is, in fact, what we have observed.

Now, one of the interesting aspects of this that I wish to spend a bit of time on today is how the deep ocean has changed. The oceans are vast. The Pacific Ocean alone covers over 40 percent of the planet. The average depth is about 2 miles. And so, as we hear a lot of talk about variation on land and the measurement of land temperature, the ocean is sampled in a different way. It has historically been sampled by ships, by oceanographic vessels, but also by other ships that have done routine measurements of ocean temperature and sometimes ocean temperature at depth as well.

So, what was implemented in the early 2000s was a major new effort to understand how the ocean heat content is changing at great depth. If we could put up the second slide. This is also from my written testimony; it is Figure 2 in the written testimony.

What we now know from this array of about 3,500 buoys that are moving around the oceans at all times covering all areas of the ocean, areas that are not typically well sampled, is that most of the heat that has been put into our Earth climate system as a result of greenhouse gases is actually in the ocean.

More importantly, these new sensing systems allow for precise detection of how this is changing over time. And so what we see is that the change over time in the deep ocean heat content—and this is a graphic that I have in my written testimony—has increased steadily over time, and we now know it with increasing precision because of these buoys that are moving about the world's oceans and constantly monitoring the deep ocean heat content.

When I began my career in ocean science, most ocean scientists could not have imagined that the deep ocean—which we knew in many areas had been at constant temperature for decades and even a century—would change in our lifetimes. We now see it is everywhere.

Now, this has implications for sea level rise. It also tells us, as we see this steady trend of increase in the ocean, deep ocean heat content, that the noise and the signature on land, and statements such as, well, it really hasn't warmed much in the last 10 years, you can see that the ocean has warmed steadily over the last 10 years. So, whereas on land there are questions about where the observations are and local variation, these get smoothed out in the ocean.

Now, I would like to turn to another subtle part of how this all plays in. As the deep ocean warms, of course the ocean continues to expand. As the mercury warming in the thermometer rises, the ocean warms; it will rise.

If you look at the estimations of how sea level would rise over time, estimations that would have been made a decade or two ago, we did not have a really good understanding of how the deep ocean was responding. We do now. So estimates of sea level rise and projections of sea level rise are going to be much more precise in the future.

Another term in sea level rise is the loss of ice from glaciers in the Arctic and the Antarctic. Again, with satellite measurements to inventory the amount of ice in Greenland and Antarctica, we can now see very precisely how it is changing. So this, in addition, gives us increased confidence and understanding. You cannot project something, you cannot predict a trend, unless you know what is causing it. But with these new measurements now, in the ocean and with ice, we understand much more than we did a decade ago about sea level rise.

We also note changes in Arctic sea ice are affecting climate. Believe it or not, if you lose ice in the Arctic, you can bring more cold air down into the center of the United States. Papers published on this in the last couple of years have shown the role of large undulations in the jet stream. You have less ice in the Arctic, you lose the insulation. So the ocean, the warm ocean, the moist ocean, loses heat and loses moisture to the atmosphere. If that moves south to where we are, we can actually get not only more snow but more cold weather.

I would like to conclude then with a slide on sea level rise. So 40 percent of the world's population lives about 60 miles from the coast. And we know that the rate of sea level rise is increasing. We know that it is increasing now at a rate of about three times what it did a century ago. And we know that the projections made only a decade ago, very cautious projections because we did not understand what was happening on Greenland the way we do now, or the Antarctic, are going to lead to higher projections of sea level rise going forward.

So, I would like to just conclude by pointing out that we see that it is variable. The red area indicates where sea level rising is occurring at the highest levels. And the reasons for this have to do with ocean circulation.

Senator BOXER. If you could wrap it up.

Mr. MCCARTHY. I would just like to conclude by saying that there is no debate that the Earth's temperature is increasing. Over the last half-century, the atmosphere, land surface, ocean surface, and deep ocean and ice loss in polar regions have all confirmed this. And they can only be explained by the increase in greenhouse gases. There is no scientific evidence that refutes this conclusion.

Thank you.

[The prepared statement of Mr. McCarthy follows:]

Testimony of

James J. McCarthy

Alexander Agassiz Professor of Biological Oceanography

Harvard University

before

United States Senate Committee on Environment and Public Works

on

Update on the Role of the Oceans in Climate Extremes and Rising Sea Level

1 August 2012

Chairman Boxer, Ranking Member Inhofe, and Members of the Committee, thank you for this opportunity to provide an update on the role of the oceans in climate extremes and rising sea level. Ocean processes are linked to many of the extreme weather events on land. Recent observed changes in the ocean, many of which only a few decades ago were thought unimaginable in our lifetimes are now occurring as result of human-caused climate change.

My hope today is to show clearly what some recent studies of the ocean are now telling us about how climate is changing and contributing to the growing intensity of extreme weather events on land.

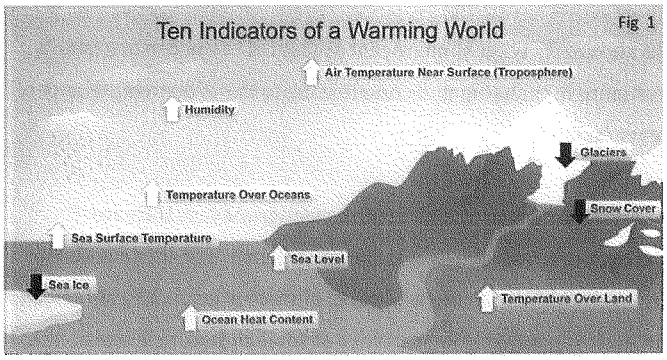
I am the Alexander Agassiz Professor of Biological Oceanography, at Harvard University, where I teach courses on ocean and climate science. For the past four decades my research has delved into many aspects of climate science. I have been also involved in the planning and implementation of several climate science research programs and assessments of climate science. From 1997 to 2001, I was the leader of Working Group II of the Intergovernmental Panel on Climate Change (IPCC), which had responsibilities for assessing impacts of and vulnerabilities to global climate change in the Third IPCC Assessment. I was also an author on the 2005 Arctic Climate Impact Assessment, the 2007 Northeast Climate Impact

Assessment, and the 2009 U.S. government report on Global Climate Change Impacts in the United States. I am Past-President of the American Association for the Advancement of Science, and currently the Chair of the Board of the Union of Concerned Scientists.

My own research has taken me to all the oceans – the high North Atlantic, the South Atlantic near Antarctica, the Artic, the Indian, the upwelling regions off the coasts of North and South America, the equatorial region in the central Pacific, the Sargasso Sea, the Caribbean Sea, as well as several coastal and estuarine systems.

I. How We know that Earth is Warming Globally

Half a century ago many distinguished scientists pointed to new data that demonstrated changes in the carbon dioxide concentration of the atmosphere, and argued that if this trend continued over time it would have a global effect on Earth's climate. One can imagine the check-list that would have been developed at the time – what you would want to be watching for to test the warming hypothesis – and the list would have looked something like the indictors in Fig. 1.



Consistent Trends in All these Indicators Over the Last Several Decades Provide Robust Evidence that Earth is Warming

NOAA/BAMS 2009

Many of these indicators could not, however, be measured well enough to discern trends before the 1980s, which is when Earth sensing satellites were first deployed. With variation from year to year, in Arctic sea ice, for example, it took time to know with confidence whether change was actually occurring. And initially some of the satellite data seemed to contradict land surface measurements, in surface temperature, for example. But with experience the new methods became reliable. For some indicators, such as sea level rise, satellite systems improved substantially the accuracy of the data.

Today there is widespread agreement among specialists who devote their careers to perfecting and deploying the myriad systems that monitor the state of these indicators that trends for all of them point as would be expected if the Earth is warming. This clear global signal becomes stronger with every passing year.

II. Observed Changes in Ocean Temperature

As an oceanographer, I have a particular interest in one of the last pieces of evidence to fall in place among these indicators – the heat content of the ocean. In the early 1980s land surface data were beginning to indicate unusual warming, but a trend in warming or cooling of even the surface ocean would be much harder to detect - vast areas of the ocean were not regularly sampled.

And, just how much change in the ocean would a scientist expect to see over the course of a career in ocean science? Until a few decades ago, the guess would have been – not very much. The oceans have an average depth of more than 12,000 feet. It takes about a thousand years for ocean currents to fully mix the oceans, and most of the deep ocean is influenced only very slowly by what happens at the surface or in the atmosphere. But more significantly, we had decades, and in some cases more than a century, of data indicating relative constancy in deep ocean conditions.

The oceans are an integral part of Earth's climate system and function as a grand flywheel. Their enormous mass and the high specific heat of water provide a

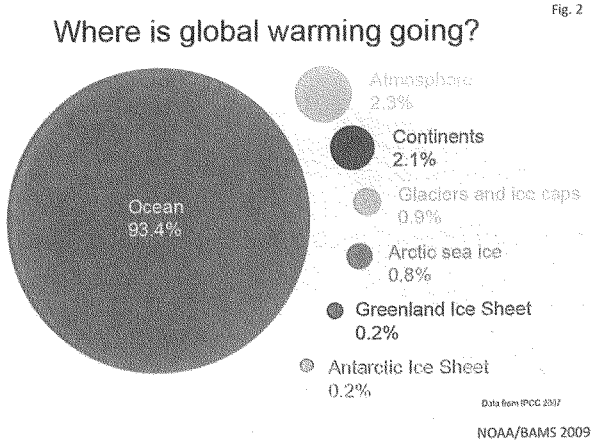
steadying characteristic that helps to dampen rates of climate change. In a running engine, a spinning flywheel helps the engine running run steadily, as individual cylinders fire in sequence. If the engine stops running the inertia of the flywheel will keep it rotating albeit more slowly as energy is lost to friction. Similarly, the ocean helps to keep climate within bounds by absorbing and releasing heat slowly, and the range of these bounds guides us, as it did our ancestors, as we make decisions as to where to plant our important crops, were to develop our cities, where and how to position our key infrastructures, etc. Ocean conditions far from land influence swings within these bounds. It's obvious that oceans influence climate in coastal regions, but changes in surface temperature in the central Pacific Ocean are linked to weather patterns thousands of miles away in the Great Plains of the United States.

We now know that the ocean is changing more rapidly than was imagined likely just a few decades ago. The additional heat in the climate system caused by the greenhouse gases that we release with our burning of fossil fuels and land use practices is now penetrating deep within the oceans.

This means that the flywheel that has helped to keep climate extremes within bounds, bounds that we have assumed would remain steady, is now is behaving differently. If these changes continue unabated we put at risk what many of us as individuals and societies hold dear – our investments in properties, commodities, and services.

With the findings of Levitus et al. (2000) and others who have confirmed these results, it is now clear that the ocean has absorbed more than 90% of the heat trapped over the past century by greenhouse gasses that have accumulated in Earth's atmosphere due to human activity (Fig. 2)

Fig. 2



NOAA/BAMS 2009

Confidence in these findings has been greatly strengthened with data from instrumented ocean buoys, known as Argo floats, that drift about the oceans at 3000 feet and every ten days descend to 6000 feet (Fig. 3). They then come to the surface and report via satellite their location, their trajectory over the prior nine days, and data for ocean temperature and salt content all along the way.

Fig. 3

Argo Drifting Floats Monitor Changes in
The Oceans' Heat Content – Initiated in the 2000s

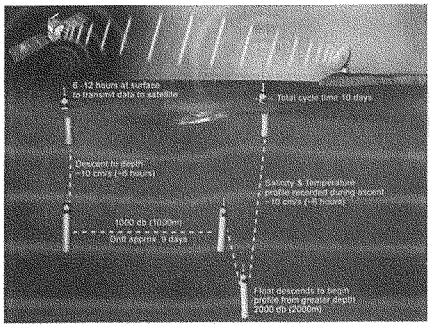
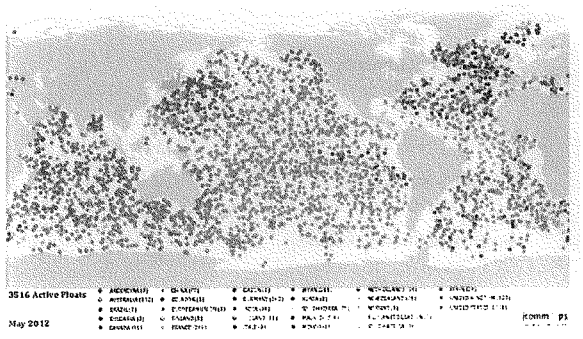


Fig. 4

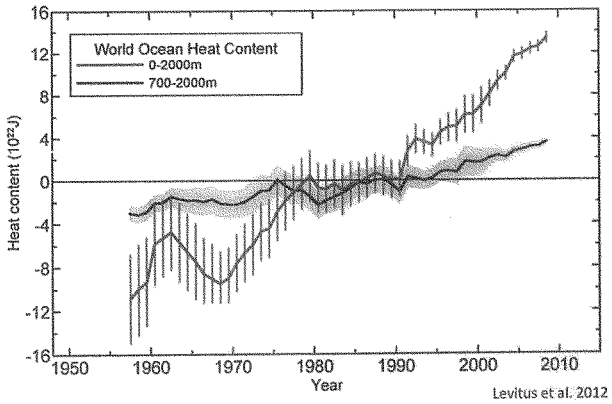
More than 3500 Drifting Argo Floats in Regular Operation
Profiling Ocean Temperature & Salinity to 2000 meters every 10 Days



This program ramped up rapidly during the 2000s, with about two-dozen nations sharing in the costs (Fig. 4). Now there are about 3500 of these floats providing data for large areas of the ocean that are rarely transited by ships. These new data have greatly improved precision in measurements of the oceans' heat content, and as can be seen in Fig. 5, the oceans have warmed steadily over recent decades.

The Deep Oceans are Warming at Great Depths

Fig. 5



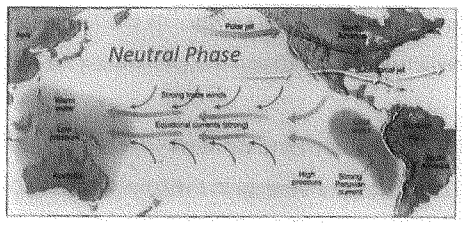
III. Atmosphere – Ocean Climate Cycles

There are many natural climate cycles. The Pacific Decadal Oscillation, the North Atlantic Oscillation, the Arctic Oscillation, the Atlantic Multidecadal Oscillation, etc., but because of their long periods we have had little opportunity to see some of these cycles repeat in the modern era of ocean science.

One, very strong and well-studied climate cycle, is the El Niño Southern Oscillation, or more commonly, simply, El Niño. Every few years (nominally 2 – 7) the trade winds that blow from east to west across the tropical Pacific Ocean relax. When this occurs the warm water that has piled up in the western Pacific flows east and elevates surface temperatures all along the Equator and along adjacent coasts of South and Central America, creating the condition known as El Niño (Fig. 6). The lens of warm water also elevates local sea-level, and during an El Niño this effect can be seen as far north as the coast of California.

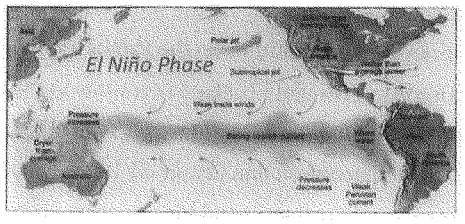
Fig. 6

Cool Ocean Water in the East and Warm in the West



With Associated Shifts In Climate Across The Globe

Every 2 – 7 yr the Trade Winds Relax, and Warm Water Flows East



When the cycle tips from El Niño back to the neutral phase, it can overshoot and create a brief exceptionally cool period, and this phase is called "La Niña".

During the strong El Niño in 1982 unusual patterns in precipitation across the American continents, Africa, southern Asia, and Australia sparked new efforts to understand the relationship between this cycle in Pacific Ocean climate and weather patterns across the globe. NOAA helped to put in place a suite of ocean surface buoys across the Pacific to detect early stages of El Niño and to provide warnings of likely effects on weather all around the tropical and temperate latitudes. At the time, the 1982 El Niño was referred to as the "El Niño of the century", but then in 1998 there was an even stronger El Niño. The ocean buoy observing system allowed forecasts well in advance of this El Niño, and in some areas the adoption of adaptive measures were highly successful.

Over the last three decades these new networks of sensing systems (deployed and maintained by NOAA in the United States), have provided the opportunity to study carefully the phases of the ENSO cycle. Fig. 6 shows the general pattern of weather that develops across the United States during an El Niño. There are also well-established patterns associated with La Niña. For example on September 8, 2011, NOAA's Climate Prediction Center issued the following forecast:

> La Niña, which contributed to extreme weather around the globe during the first half of 2011, has re-emerged in the tropical Pacific Ocean and is forecast to gradually strengthen and continue into winter.... La Niña winters often see drier than normal conditions across the southern tier of the United States and wetter than normal conditions in the Pacific Northwest and Ohio Valley...."This means drought is likely to continue in the drought-stricken states of Texas, Oklahoma and New Mexico," said Mike Halpert, deputy director of the Climate Prediction Center. La Niña also often brings colder winters to the Pacific Northwest and the northern Plains, and warmer temperatures to the southern states.

As Earth's average surface temperature continues to rise, an obvious question is how the El Niño Southern Oscillation will behave. Will El Niño's become more likely,

more intense, or more persistent if the background temperature during the neutral phase increases? There is no clear answer from model simulations and this remains an active area of research. The 1982 and 1998 El Niño's were both exceptionally strong, and it was surprising to see the second one appear so soon after the first. But recent proxy data now reveal that there was a strong El Niño in the late 1880s.

On balance the El Niño has a much broader influence than the La Niña on global climate, and even if El Niños continue with the same frequency and intensity their effects will become more damaging as they occur in a climate that is warmed by increasing concentrations of greenhouse gases.

The concurrence of three independent analyses of global surface temperature data since 1840 is shown in Fig. 7. There is notable interannual variability, and this has led some people to question the upward trend in recent years or to even suggest that warming has abated. Close scrutiny suggests otherwise when the role of the El Niño is taken into consideration.

Fig. 7

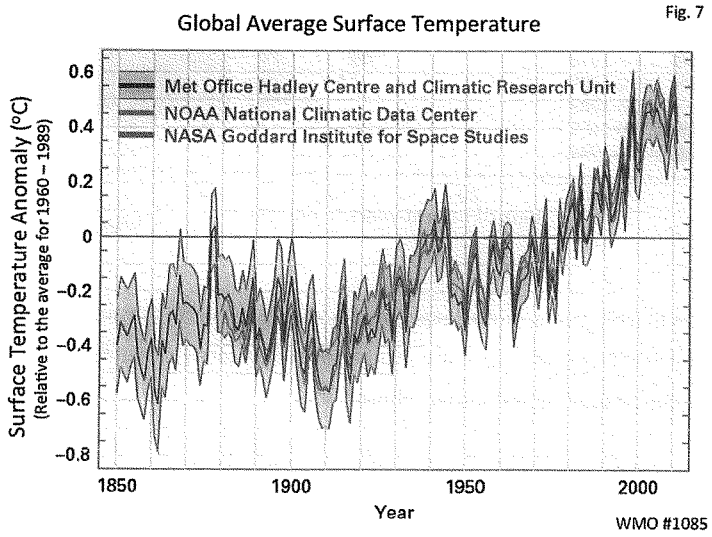
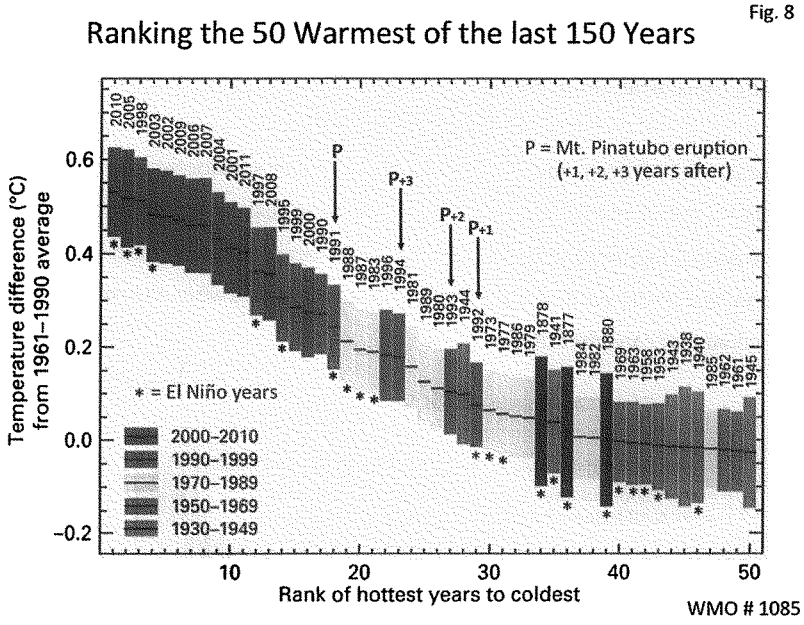


Fig. 8 is an abbreviated version of a World Meteorological Organization (WMO) figure that shows the ranking of the 50 warmest years for Earth's surface temperature since 1840. Either a single (2000s; 1990s) decade or pairs of decades (1970s + 1980s; 1950s + 1960s; 1930s + 1940s) are binned and assigned a color. Note that two colors are not in the legend: the singular deep red for 2011 (the 11th warmest year) and the three darkest blue for 1877, 1878, and 1880.

Fig. 8



An * symbol marks El Niño years, and as expected the warmest years for each of the colors are typically El Niño years. There are just two El Niño years (1973 and 1977) that do not rise to the head of their decadal cohort.

Another natural phenomenon that can influence global climate is significant volcanic eruption. The last major volcano to be large enough to affect global climate significantly was Mt. Pinatubo in the Philippines during June 1991. Satellite systems

allowed for the estimation of tiny particles – aerosols – released to the upper atmosphere by this eruption, and climate modelers at that time predicted that the following few years would be cooled by the aerosol reflection of solar energy. Note in Fig. 8 that 1992 was the coolest in its decadal bin, 1993 was the second coolest, 1994 was the third coolest. The prior large volcanic eruption was El Chicon in Mexico in 1982. Since 1982 was a major El Niño year, this one is a little more complicated, but the same pattern of response to an aerosol injection plays out in the years following the eruption of El Chicon. Looking ahead, we can't predict volcanic eruptions, but some will surely occur.

Another natural source of variability is in the luminosity of the sun. An eleven-year cycle in sunspot activity was first documented in the mid 1800s, but it wasn't until satellites began orbiting Earth in 1980 that the actual variation in solar activity over a sunspot cycle could be measured precisely.

The Sun's energy recently reached a minimum in the eleven-year cycle, so over the next few years Earth will receive more intense solar irradiance. In fact:

> "This week researchers announced that a storm is coming--the most intense solar maximum in fifty years. The prediction comes from a team led by Mausumi Dikpati of the National Center for Atmospheric Research (NCAR). 'The next sunspot cycle will be 30% to 50% stronger than the previous one,' she says. If correct, the years ahead could produce a burst of solar activity second only to the historic Solar Max of 1958." (http://www.auroraborealispage.net/solarmax.html: 23 July 2012)

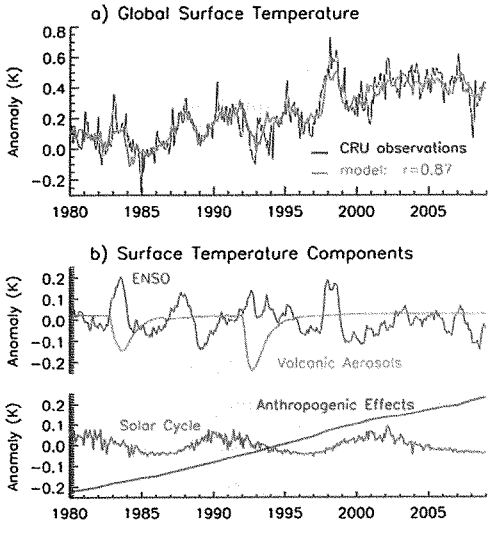
Interestingly, 1958, also an El Niño year, was the warmest year between 1950 and 1970 (Fig. 8).

Thus, over the past three decades, the known drivers of climate variation can now be measured directly and put into common units of energy. Many climate research

groups have done this, and a good example is the work of Judith Lean (a solar physicist at the Naval Research Laboratory) and David Rind (a climate modeler at NASS). When greenhouse gases, aerosols, (including volcanic), solar variability and El Niño events are assembled over time to forecast Earth's surface temperature a remarkably realistic simulation emerges (Fig. 9). This is not curve fitting. It is rather a test to see if there are any significant missing components and a way of assessing the relative contribution of each of the components.

Reconstructing Earth's Climate 1980 – 2009
Using Observed Climate Forcing Functions

Fig. 9



When The Effects of Solar Variability, El Niños, Volcanoes And Greenhouse Gases Plus Aerosols, etc. are Summed, Models Faithfully Reproduce Recent Trends In Earth's Surface Temperature

Lean and Rind 2009

There are many published examples of these sorts of analyses by climate modeling groups in the US and abroad. The consistent conclusions are that most of the observed warming over the past half century results from increasing greenhouse gasses, that the variation from year to year is strongly influenced by El Niño events and volcanoes, and that solar variability is playing a relatively small role in climate change.

The final component, that of the human generated greenhouse gases that remain in the atmosphere shows little or no evidence of cycles. Rather its trend is that of a steady secular increase with small wiggles reflecting economic shifts and politics.

Thus, in the future, as in the past, global average temperatures will be unusually warm during El Niño years and during peak years for solar activity. In the future, however, if greenhouse gases continue to increase, strong El Niños will wreak even more havoc as they break old records for warm and wet conditions across much of the globe, because they will be occurring upon a higher baseline of warming.

The answer to the question of just how intense new extremes in heat and precipitation will be, in part will be answered with the choices that we make about our practices and policies that release greenhouse gases to the atmosphere.

IV. Observed Changes in Arctic Climate

A. The Arctic Ocean

A dozen years ago the news that Arctic sea ice was thinning and that during late summer there were large areas of open water in the central Arctic was surprising. Models had long projected that the Arctic would warm faster than other regions as atmospheric concentrations of greenhouse gases increased, but summer sea ice was being lost faster than the models projected. Part of the explanation may lie with the role of small soot particles from diesel combustion and fires that is blown north from lower latitudes. Though tiny, these dark particles increase the rate of snow and ice melt across the Arctic.

As is evident in Fig. 10, the summer extent of Arctic sea ice has declined since the satellite measurements for sea ice began in 1979, and it has thinned even more rapidly. Annually Arctic sea ice reaches its winter maximum in March and its minimum in September. As can be seen in Fig. 11, recent data indicate that new record lows for sea ice extent have been set during June and July 2012. The sea ice

melt season began earlier this year, and the extent of open water now in the Kara and Barents Seas (north of Norway and western Russia) would typically not be seen until September.

Fig. 10

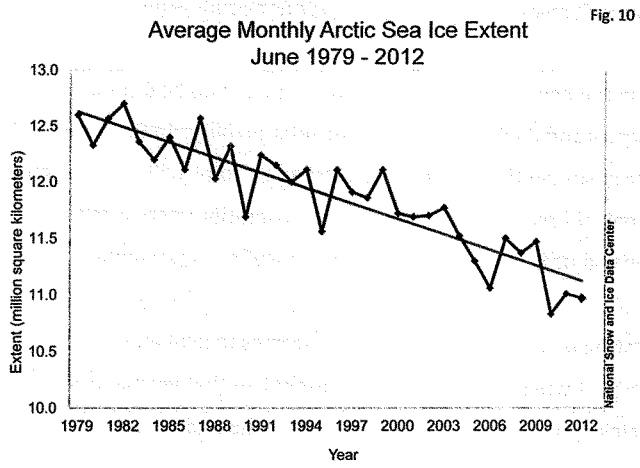
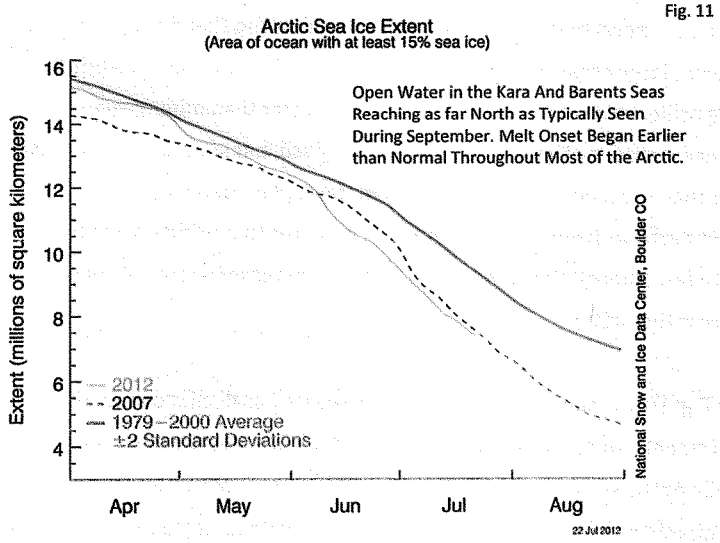


Fig. 11



Will someone who doesn't live in the Arctic be affected if the Arctic continues to warm and the area of sea ice continues to decrease during summer? New research shows links between the summer loss of Arctic sea ice and unusual extreme weather conditions across the temperate regions of North America and Eurasia (Overland et al. 2010). Ice atop water acts an insulator. Without an ice cover the surface ocean releases heat and water to the atmosphere. What most limits winter snowfall across much of North America is not temperature in winter, but rather availability of water vapor. It is often cold enough to snow but doesn't. More open water in the Arctic and in lakes increases the potential for snow across large continental regions.

New studies (Francis and Vavrus, in press) show how warming in the Arctic can also influence the path of the upper atmospheric Jet Stream, creating higher amplitude waves, and in effect slow the propagation of weather patterns across the central North America. The result is that both warm periods and cold periods persist longer, potentially creating weather extremes on both ends of the scale. The authors suggest that this was in play during winter 2010-11, when record snow and cold occurred across parts of the central and eastern US just as record high temperatures were occurring across central Canada. During winter 2011-12 the La Niña also had a strong influence on the path of the Jet Stream – it was relatively flat rather than undulating – thus keeping cold air masses further north than usual.

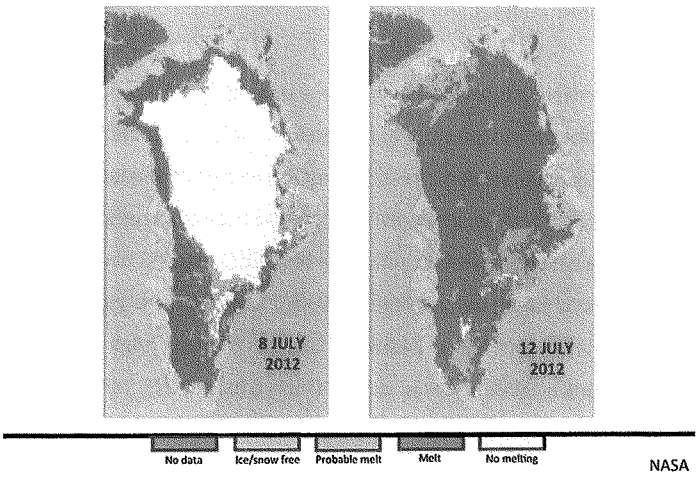
It is also now well established that these changing ice conditions in the Arctic are affecting the exchanges of water between the Arctic Ocean and the north Atlantic Ocean in unusual ways (Speilhagen et al. 2012), and with unknown implications for future climate across regions bordering the North Atlantic.

B. Glacial ice melt

There was a lot of press coverage recently about an unusual Greenland melt event (Fig. 12). Greenland is covered by the most substantial mass of glacial ice in the northern hemisphere. It accounts for 10% of the surface fresh water on the planet. This ice cap is a broad flat dome that rises to about 10,500 feet, and were it all to

melt global sea level would rise 22 feet. About a decade ago satellite images began to show that summer surface melting was occurring at increasing elevations and blue melt pools were beginning to appear above 6000 feet. These pools eventually drain through fissures in the ice, and probably speed the flow of glacial ice as it move along the solid bedrock. It is not terribly surprising that something like the recent July warm condition occurred. The white area of "no melting" in this image doesn't indicate just how much below freezing any of this area actually is.

Rapid Melt on Greenland Surface during July 2012 Fig. 12



According to NASA reports there is evidence in the ice core records of a strong warming event over Greenland in the 1880s. Data in Fig. 8 for global temperature show that the 1880s were unusually warm. As the Arctic continues to warm summer melting snow and ice at all elevations on Greenland will become more common.

This past July Greenland was also in the news for the release of an iceberg roughly twice the size of Manhattan from the Petermann Glacier in NW Greenland. Satellite data now allow for very precise estimates of the mass of Greenland ice and changes in its outlet glaciers, which drain ice from the ice cap to lower elevations. Fig. 13

shows terminations of the major outlet glaciers, with black for those with land terminations and green for those with marine terminations, also known as tidewater glaciers.

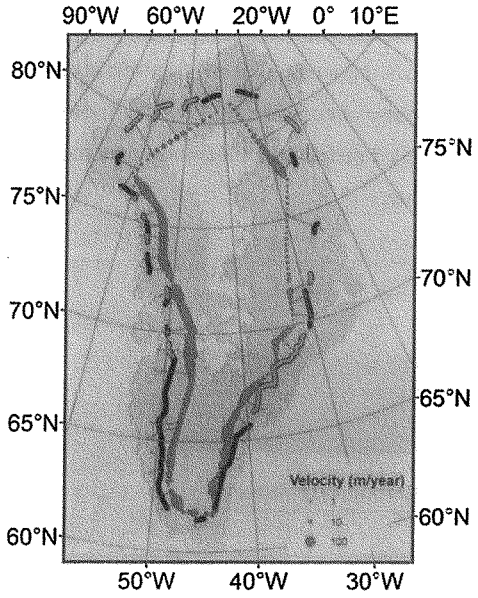


Fig. 13

Rates of Glacial Motion and Locations of Greenland Outlet Glaciers with Terrestrial (black) and Marine (green) Terminations

"On the basis of calculations presented here, we suggest that an improved estimate of the range of sea level rise to 2100 including increased ice dynamics lies between 0.8 and 2.0 meters [31 – 78 inches]."

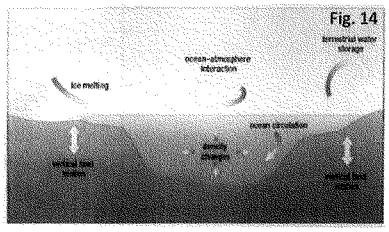
Pfeffer et al. 2008

The greatest changes in Greenland glaciers over the past decades have been the rapid retreats of tidewater glaciers like Petermann. While conditions at higher elevation certainly affect glacial flow, the factor most likely responsible for the retreat and shedding of large icebergs by Greenland's tidewater glaciers is the warming of waters surrounding Greenland and their melting influence on the snouts of these glaciers. The string of red dots of varying sizes on Fig. 13 circumscribe the edges of the high ice cap and indicate, from satellite data, the best estimates for rates of glacial discharge (largest of the three sizes of red dot is 100 times faster than the smallest red dot). Note that the weight of this mass of ice depresses the center of Greenland below the sea level surrounding Greenland.

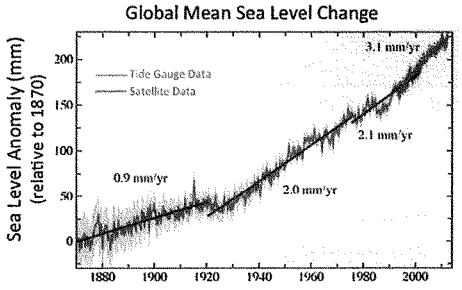
V. Sea Level Rise

Sea level is influenced by several factors (Fig. 14). Globally the ocean's heat content and the amount of land ice are dominant factors. As the ocean warms, its volume increases and sea level rises. A warming atmosphere and ocean cause land ice to melt, and if this water reaches the ocean, it too contributes to sea level rise. Other factors, such as coastal uplifting or subsidence of the land will strongly affect local manifestations of sea level. Importantly, the rise of an ocean that is warming and receiving more water from ice melt on land isn't distributed uniformly across the world's oceans. I will return to this point shortly.

Contributing Components to Local and Global Sea Level



Tide Gauge and Satellite Data for Sea Level 1870 - 2012



The rate of sea level rise has increased in recent decades, and is today greater than the conservative projections made by the IPCC one or two decades ago, and it is now clear that changes in sea level are speeding up.

In 2001, the IPCC reported that "[w]ithin present uncertainties, observations and models are both consistent with a lack of significant acceleration of sea level rise during the 20th century" (IPCC 2001). But it is now evident (Rahmstorf *et al.* 2007)

that sea-level rise has accelerated since 1990 (Fig. 14).

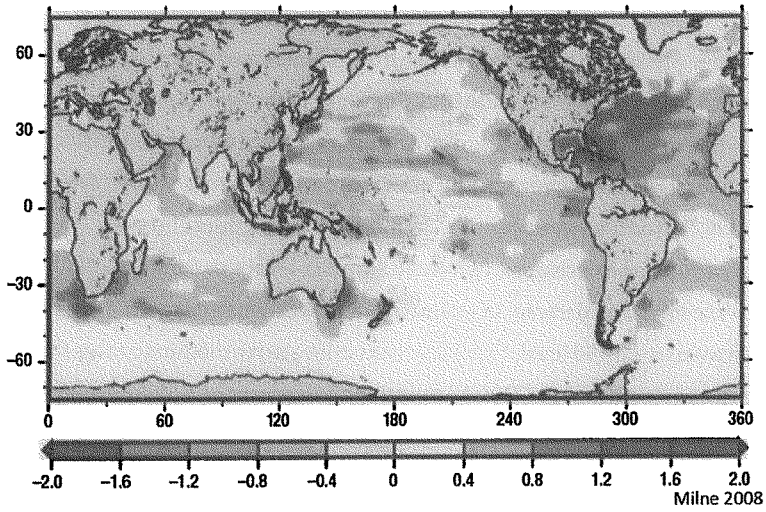
The 2007 IPCC report projected 12 – 24 inches of sea-level rise by 2100. These estimates did not preclude higher rates of rise due to increased rates of ice loss on Greenland and Antarctica. Although the IPCC authors were aware of publications relating to recent changes in Greenland and Antarctic ice, they lacked confidence that they could extrapolate meaningfully from these data to future sea-level rise. Rahmstorf (2007) used a semi-empirical relationship from 20th-century temperature and sea-level changes to project future sea-level rise from the IPCC scenarios for warming and derived an estimate of sea-level rise of about 2 – 4.5 feet for 2100 relative to the 1990 level. Using current outlet glacier discharge rates for Greenland to improve on the IPCC 2007 projections, Pfeffer *et al.* (2008) estimated a sea level rise between 2.5 and 6.5 feet by 2100 (Fig. 13).

An average sea-level rise of even 2.5 feet during this century would be of enormous consequence for lives, livelihoods, and property in coastal regions across the globe. Major cities, large portions of nations, indeed entire island nations will be affected. But for any specific locality future sea level will also be influenced by changes in currents and winds, proximity to the mass of melting ice sheets, and on the vertical movements of the land due to geological processes.

For example, a 2-foot rise in global sea level by the end of this century would result in a relative sea-level rise of 2.3 feet at New York City, 2.9 feet at Hampton Roads, Virginia, 3.5 feet at Galveston, Texas, and 1 foot at Neah Bay in Washington State (Karl et al. 2009). The southeastern and eastern coasts of the US have already experienced greater than average rates of increase over the last half-century (Fig. 15).

Trends in Sea- Level Change (mm/yr) due to Warming from 1955 to 2003

Fig. 15



In the Gulf Coast area alone, an estimated 2,400 miles of major roadway and 246 miles of freight rail lines are at risk of permanent flooding within 50 to 100 years as global warming and land subsidence (sinking). Seven of the 10 largest ports (by tons of traffic) are located on the Gulf Coast.(Karl et al. 2009) The US Navy estimates that $100 billion of Navy installations would be at risk with a sea level rise of about 3 ft. (NRC 2011)

VI. Personal Reflections on a Scientist's Journey

Scientific knowledge is always evolving. Science progresses because scientists constantly question every aspect of scientific understanding. New findings, seemingly credible, and perspectives that prevailed for decades are sometimes proven to be wrong. The process of science is one of always questioning and challenging both the new and the well-established findings.

A scientist is always asking: Does evidence adequately support the prevailing view as to how a particular process works? Is there an alternative explanation that is also, or perhaps even more, consistent with the highest quality evidence?

All good scientists ask these questions about everything they have either been taught or have discovered themselves. We train our students to go beyond what we can teach them – to use newer methods for gathering evidence, to subject their data to ever more sophisticated analyses, to always keep their mind open to other views in order to advance, in the most genuine sense of the word, the science. The very best students will discover errors and inadequacies in what their mentors thought to be the best understanding of the natural world.

For many of us in ocean science the compelling evidence for human-caused climate change came with the observations of deep ocean warming, the ice core data that demonstrate linkages between Earth's past temperature and atmospheric greenhouse gas content, the acceleration in sea level rise, the abrupt melting of land ice and ice shelves that had been in place for many thousands of years, and global changes in ocean chemistry. Such changes in these phenomena can only be consistently explained by an unusual rate of greenhouse gas release to the atmosphere.

The idea that greenhouse gases from fossil fuel combustion affect climate, which was studied by Arrhenius more than a century ago and developed further by Calendar a half century later, is correct. Interestingly, Arrhenius did not anticipate the rapid growth in human population during the 20th century and our increasing demands for energy - he thought that it would take millennia rather than a just a century to double the pre-industrial atmospheric CO_2 concentration.

State of the art fully coupled climate models can now simulate the natural processes that affect climate (solar cycles, volcanoes, and internal cycles such as the El Niño – Southern Oscillation) and the human-caused processes that affect climate

(greenhouse gases and aerosols) to show the relative importance of each of these components in the climate of the past and present. Using assumptions about trends in population, type of energy used, etc. these same models can make projections about future climate. One very clear finding from these studies is that one of the largest uncertainties about future climate relates to the choices that we and our children will make regarding energy use. The more dependent we are on CO_2-emitting sources of energy, the more Earth's climate will change.

In the public media there is a lot of confusion about climate science. Most National Academies and professional societies have issued statements about climate science. The American Meteorological Society, for example, in a 2007 two-page statement says:

> "Despite the uncertainties noted above, there is adequate evidence from observations and interpretations of climate simulations to conclude that the atmosphere, ocean, and land surface are warming; that humans have significantly contributed to this change; and that further climate change will continue to have important impacts on human societies, on economies, on ecosystems, and on wildlife through the 21st century and beyond."

Other professional organizations of ocean and atmospheric scientists and National Academies have issued similar statements.

It can be tempting to think that any of us know better than the experts, or that the risks don't apply to us. Early in my life I had many friends and family who smoked cigarettes. But most of them stopped when organizations such as the American Medical Association, the American Cancer Society, the American Lung Association, the American Association for Thoracic Surgery, etc. issued statements saying that smoking contributes to lung and heart disease. Some continued smoking because habits are hard to break, and others continued because they thought that it couldn't be said with certainty that they would get cancer.

This same sense of self-preservation and responsibility for our actions that will affect future generations should motivate us to wisely use knowledge from climate science to reduce risks of harm from unnecessarily disruptive climate.

Thank you for inviting me to contribute to this discussion.

****

References

BAMS/ NOAA (2009) http://www.ncdc.noaa.gov/bams-state-of-the-climate/

Frances, J.A. and S.J. Varvus (in press) *Geophys. Res. Lett.*

IPCC (2001) Working Group 1, Summary for Policy Makers. http://www.ipcc.ch/

Karl, T. R., J.M. Melillo, T.C. Paterson (eds.) (2009), *Global Climate Change Impacts in the United States.* Cambridge University Press.

Lean, J.L., D.H. Rind (2009) *Geophys. Res. Lett.* 36, L1570

Levitus, S., J. Antonov, T.P. Boyer, C. Stephens (2000), *Science* **287**, 2225.

NRC (2011) Naval Studies Board, Natl Acad Press

Overland, J.E. and M. Wang (2010) *Tellus 62A, 1–9*

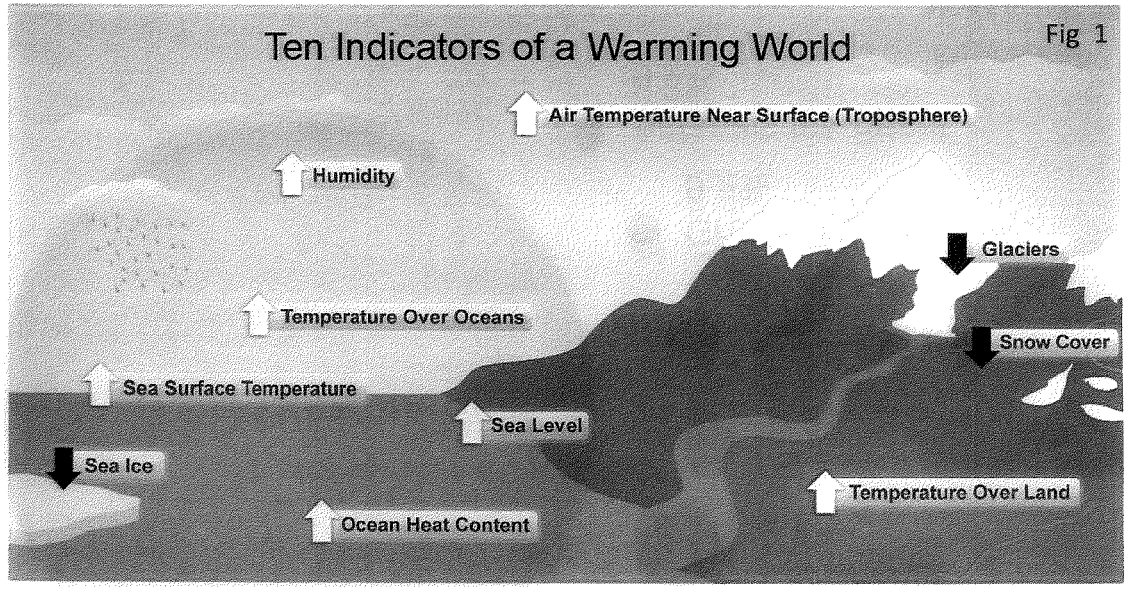
Pfeffer, W.T., J. T. Harper, S. O'Neel (2008), *Science* **321**, 1340.

Pritchard, H.D., R. J. Arthern, D. G. Vaughan, L. A. Edwards (2009), *Nature* **461**, 971.

Rahmstorf, S. et al.(2007), *Science* **316**, 709..

Rahmstorf, S. (2007), *Science* **315**, 368.

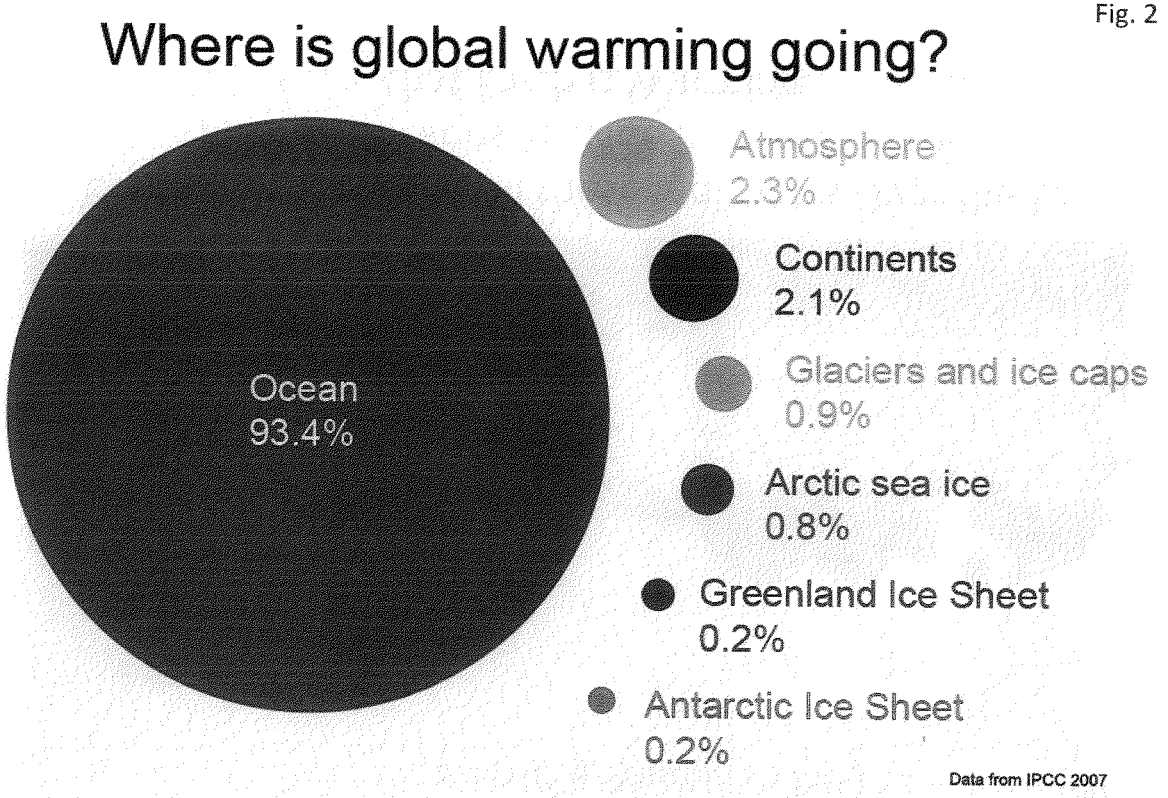
Speilhagen, R.F. et al. (2012) *Science* **331**, 450



Consistent Trends in All these Indicators Over the Last Several Decades Provide Robust Evidence that Earth is Warming

NOAA/BAMS 2009

Fig. 2



NOAA/BAMS 2009

Fig. 3

Argo Drifting Floats Monitor Changes in The Oceans' Heat Content – Initiated in the 2000s

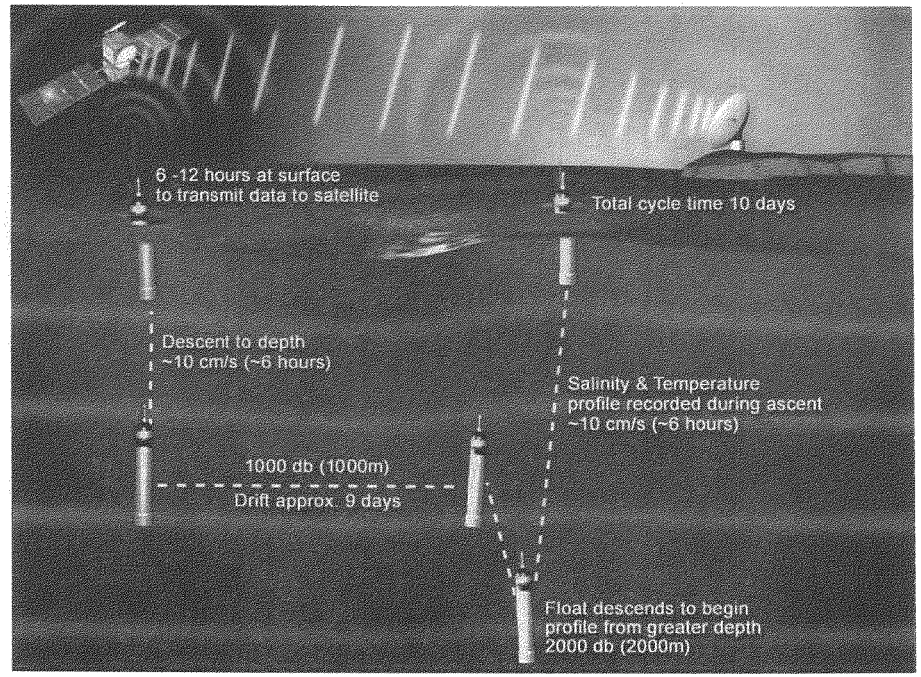


Fig. 4

More than 3500 Drifting Argo Floats in Regular Operation Profiling Ocean Temperature & Salinity to 2000 meters every 10 Days

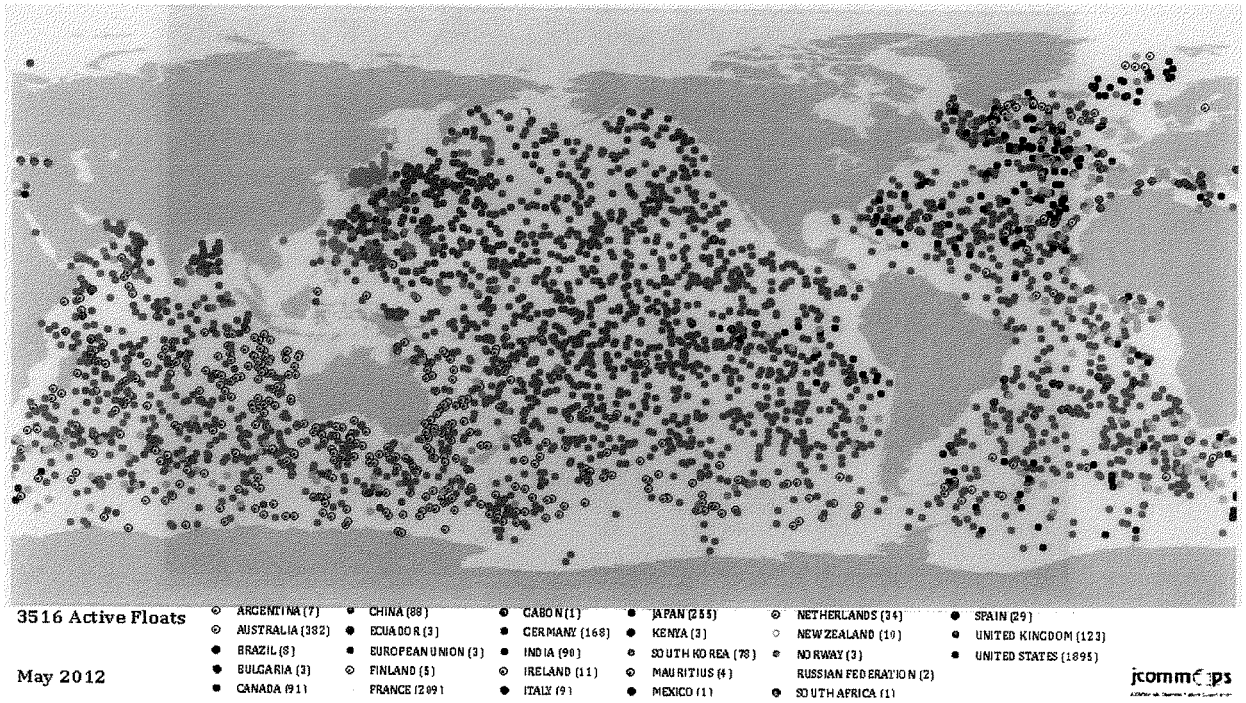


Fig. 5

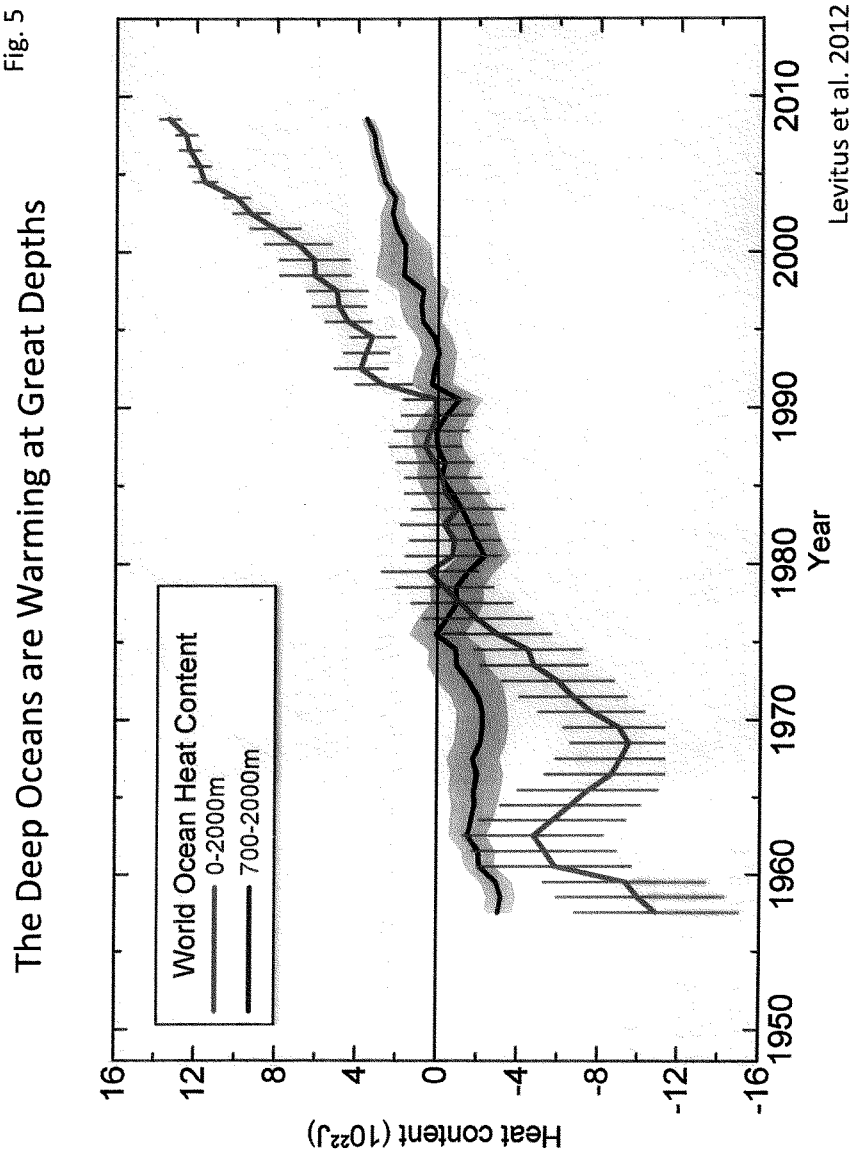
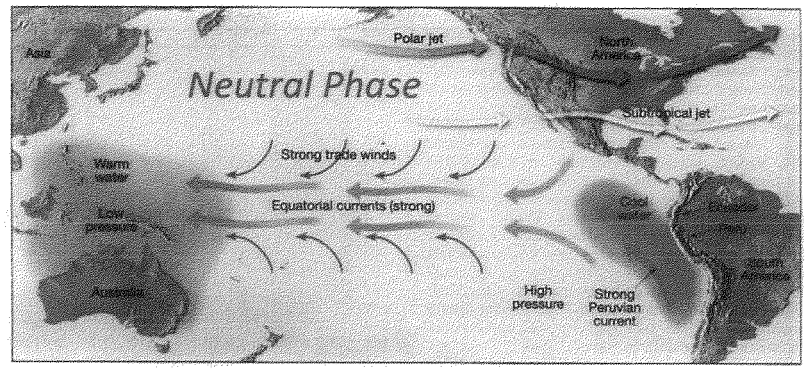

The Deep Oceans are Warming at Great Depths
World Ocean Heat Content
0-2000m
700-2000m
Heat content (10^{22}J)
16
12
8
4
0
-4
-8
-12
-16
1950
1960
1970
1980
1990
2000
2010
Year
Levitus et al. 2012

Fig. 6

Cool Ocean Water in the East and Warm in the West



With Associated Shifts In Climate Across The Globe

Every 2 – 7 yr the Trade Winds Relax, and Warm Water Flows East

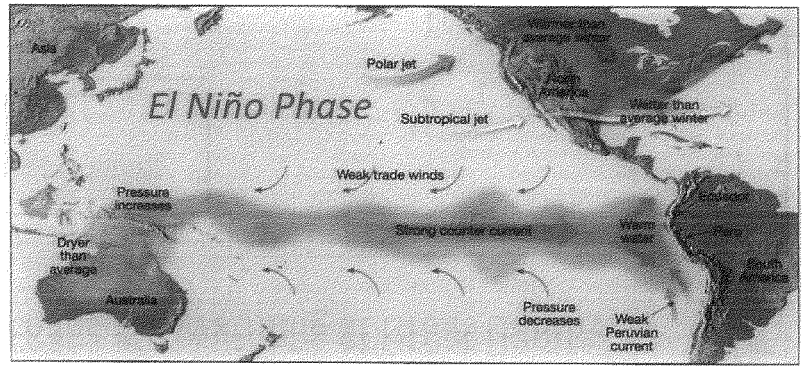


Fig. 7

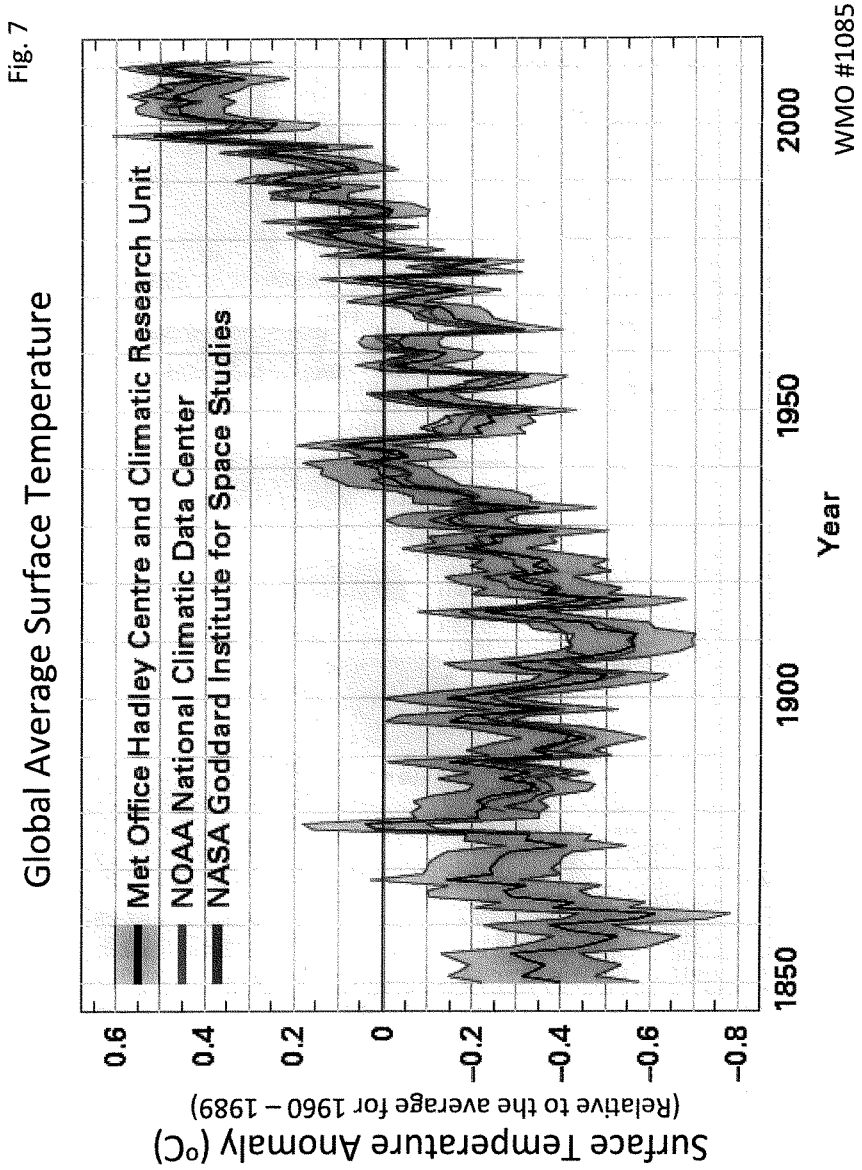
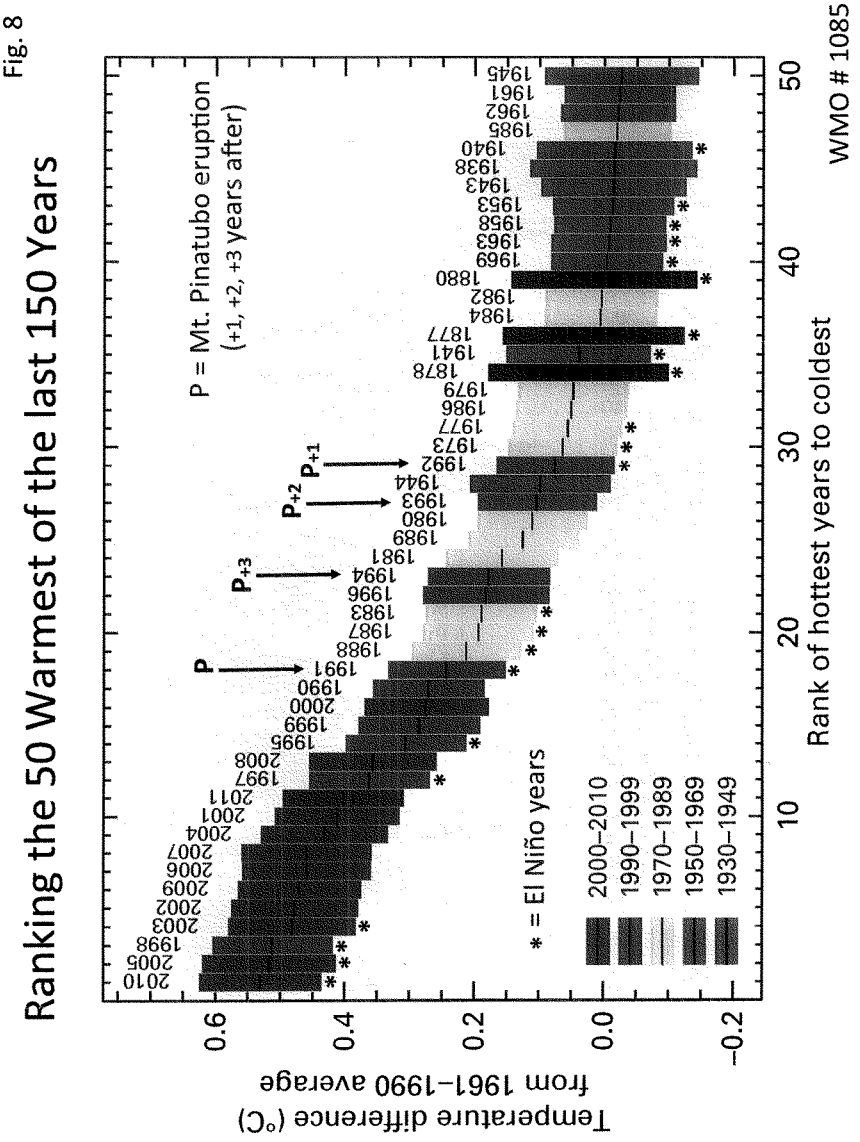
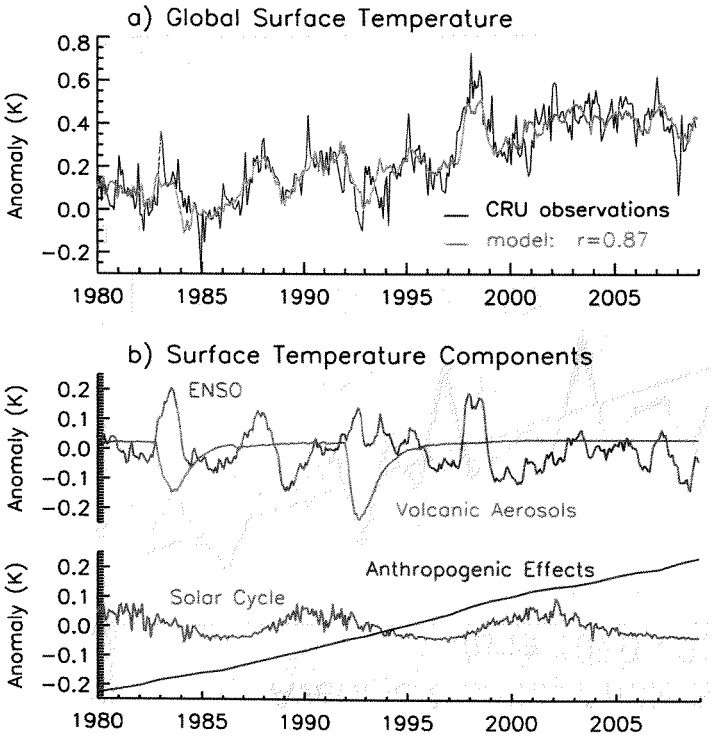

Global Average Surface Temperature
Met Office Hadley Centre and Climatic Research Unit
NOAA National Climatic Data Center
NASA Goddard Institute for Space Studies
Surface Temperature Anomaly (°C)
(Relative to the average for 1960 – 1989)
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
1850
1900
1950
2000
Year
WMO #1085

Fig. 8


Ranking the 50 Warmest of the last 150 Years
P = Mt. Pinatubo eruption
(+1, +2, +3 years after)
P
P+1
P+2
P+3
* = El Niño years
2000–2010
1990–1999
1970–1989
1950–1969
1930–1949
Temperature difference (°C)
from 1961–1990 average
Rank of hottest years to coldest
WMO # 1085
2010
2005
1998
2003
2002
2009
2006
2007
2004
2001
2011
1997
2008
1995
1999
2000
1990
1991
1988
1987
1983
1996
1994
1981
1989
1980
1993
1944
1992
1973
1977
1986
1979
1878
1941
1877
1984
1982
1880
1969
1963
1958
1953
1943
1938
1940
1985
1962
1961
1945

Reconstructing Earth's Climate 1980 – 2009
Using Observed Climate Forcing Functions

Fig. 9



When The Effects of Solar Variability, El Niños, Volcanoes And Greenhouse Gases Plus Aerosols, etc. are Summed, Models Faithfully Reproduce Recent Trends In Earth's Surface Temperature

Lean and Rind 2009

Fig. 10

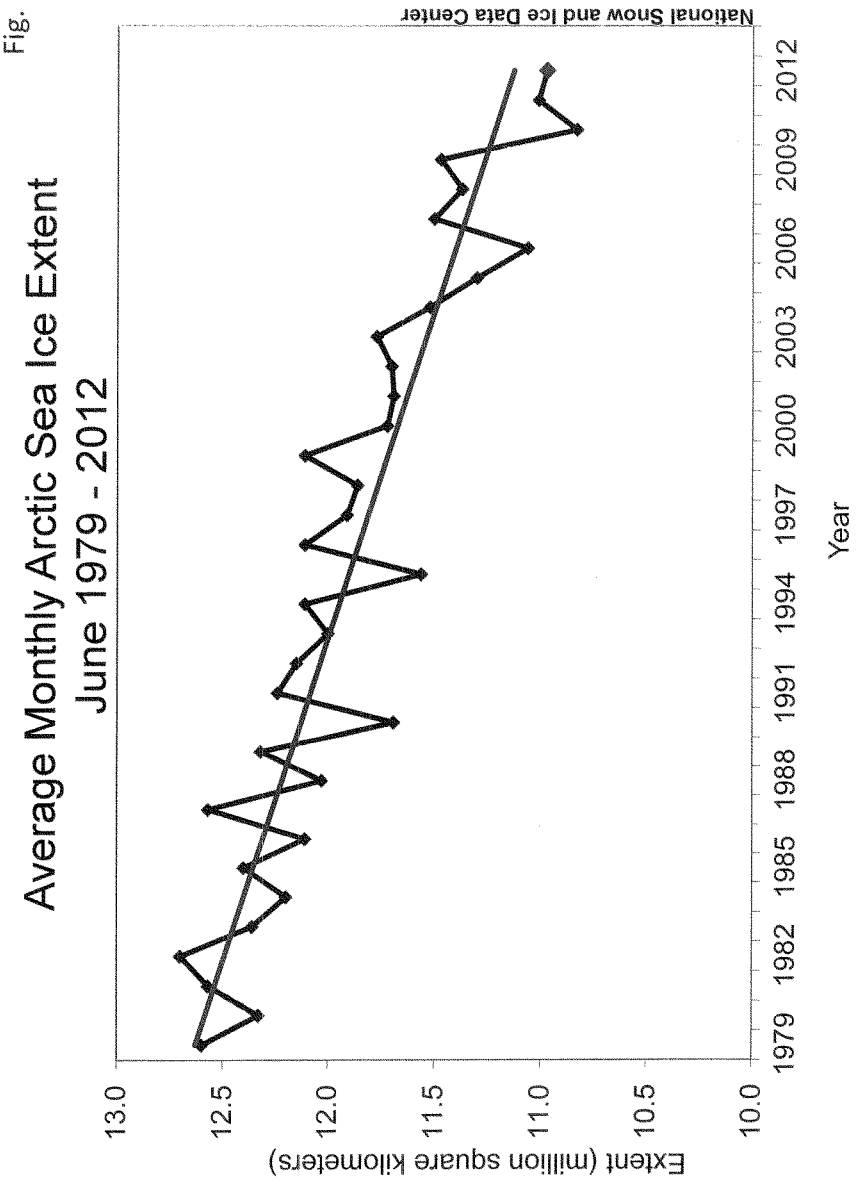
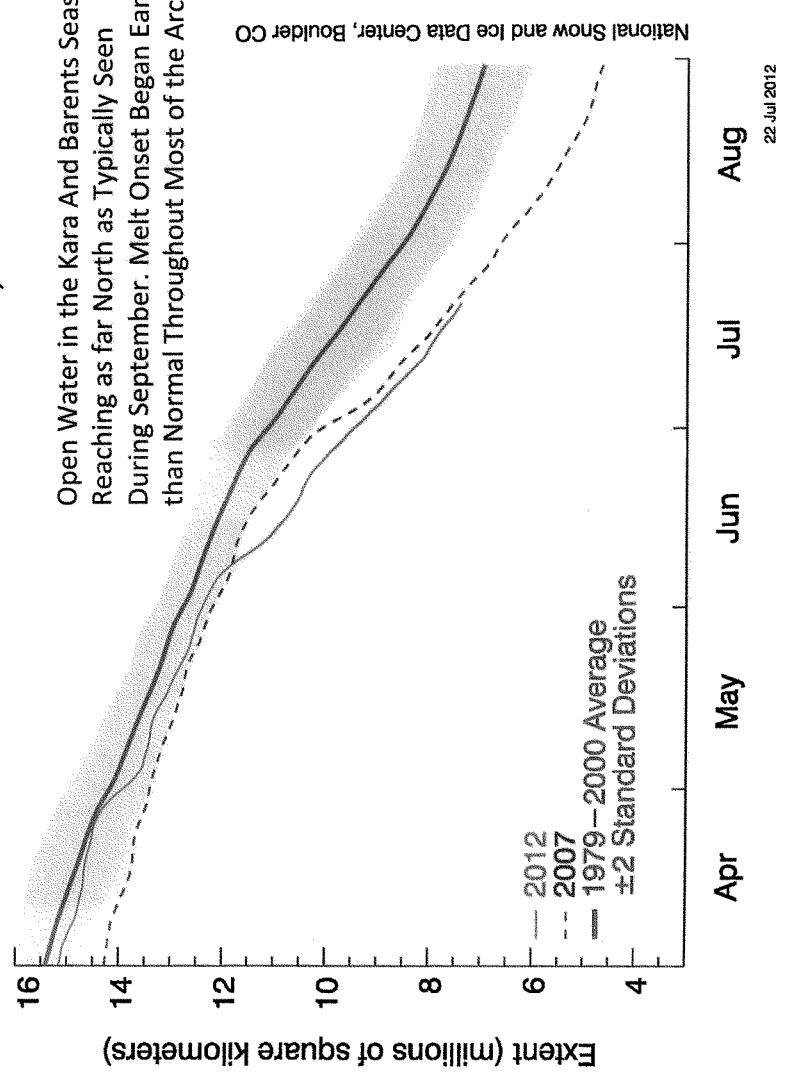
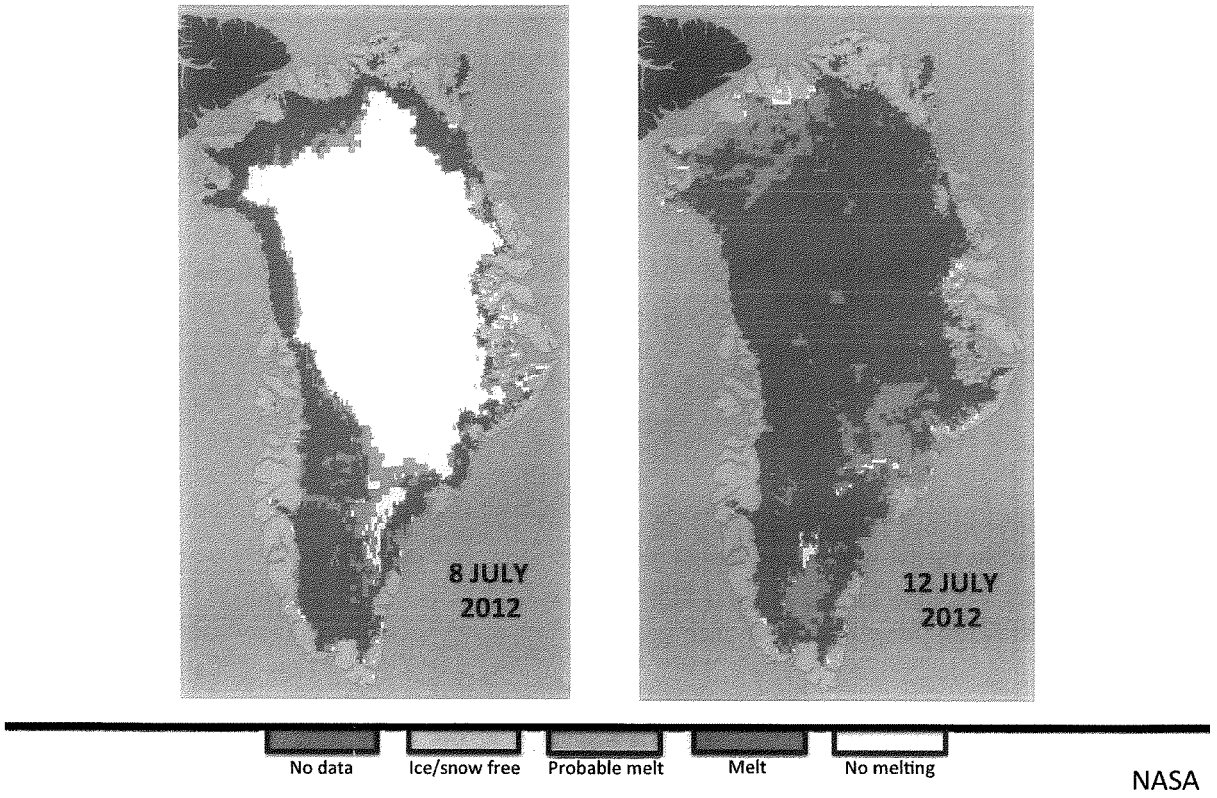

Average Monthly Arctic Sea Ice Extent
June 1979 - 2012
National Snow and Ice Data Center
Extent (million square kilometers)
13.0
12.5
12.0
11.5
11.0
10.5
10.0
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
Year

Fig. 11


Arctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)
Open Water in the Kara And Barents Seas
Reaching as far North as Typically Seen
During September. Melt Onset Began Earlier
than Normal Throughout Most of the Arctic.
National Snow and Ice Data Center, Boulder CO
Extent (millions of square kilometers)
16
14
12
10
8
6
4
2012
2007
1979–2000 Average
±2 Standard Deviations
Apr
May
Jun
Jul
Aug
22 Jul 2012

Rapid Melt on Greenland Surface during July 2012

Fig. 12



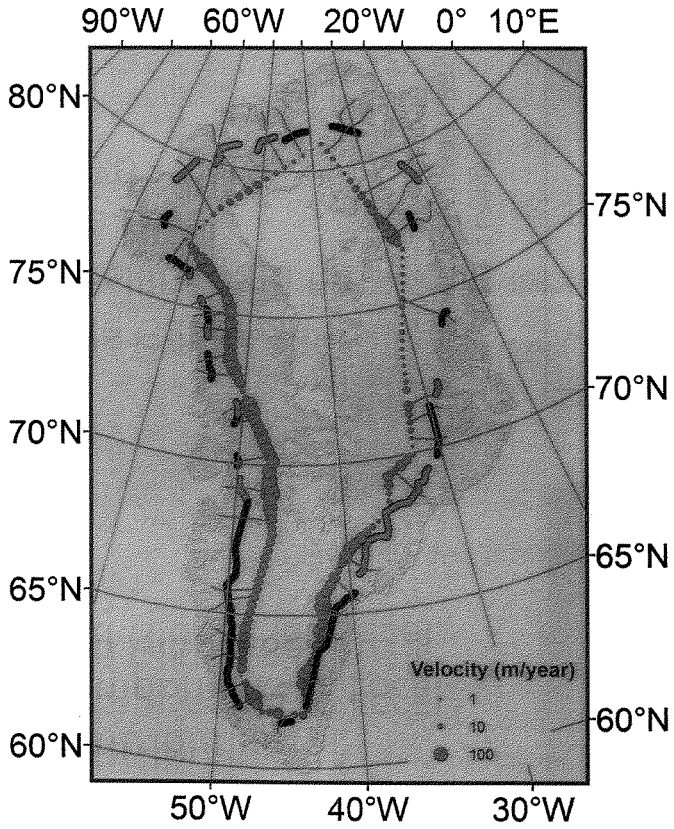


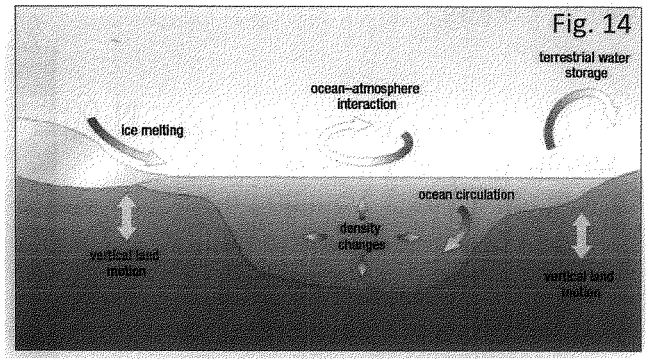
Fig. 13

Rates of Glacial Motion and Locations of Greenland Outlet Glaciers with Terrestrial (black) and Marine (green) Terminations

"On the basis of calculations presented here, we suggest that an improved estimate of the range of sea level rise to 2100 including increased ice dynamics lies between 0.8 and 2.0 meters [31 – 78 inches]."

Pfeffer et al. 2008

Contributing Components to Local and Global Sea Level



Tide Gauge and Satellite Data for Sea Level 1870 - 2012

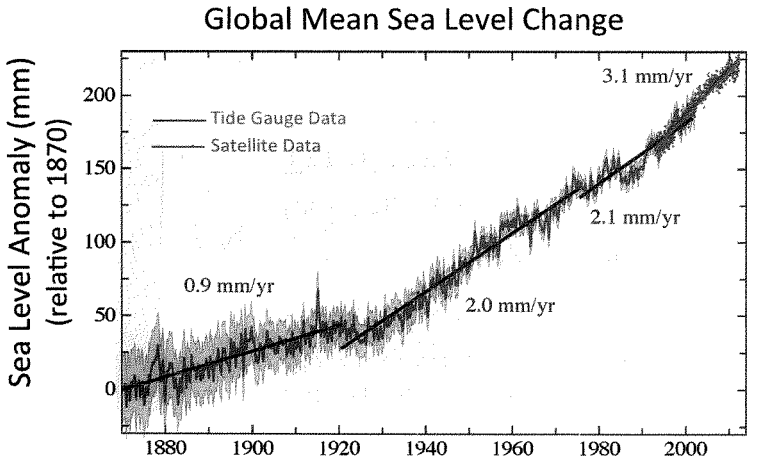
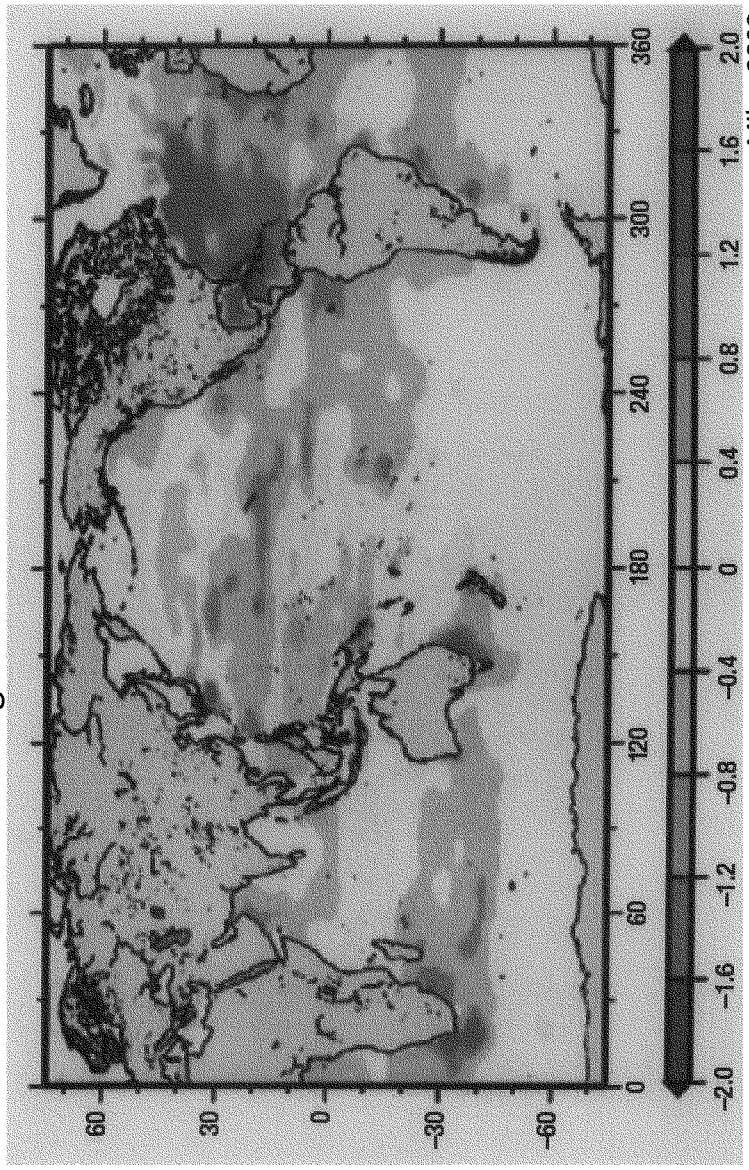


Fig. 15

Trends in Sea- Level Change (mm/yr) due to Warming from 1955 to 2003



MUSEUM OF COMPARATIVE ZOOLOGY

The Agassiz Museum

HARVARD UNIVERSITY
26 OXFORD STREET
CAMBRIDGE, MASSACHUSETTS 02138

17 January 2013

Senator Barbara Boxer
Committee on Environment and Public Works
United States Senate

Dear Senator Boxer:

Please excuse my tardy response to your letter of 27 December. I have been travelling, and for a good portion of this in electronic darkness aboard a research ship in the Gulf Stream.

You asked that I address four questions - my responses follow.

1. The National Academy of Sciences concluded "Climate change is occurring, is caused largely by human activities, and poses significant risks for – and many cases is already affecting – a broad range of human and natural systems."
Is this view shared by other scientific professional societies and academies of science around the world?

Within the United States all professional societies and organizations of atmospheric, ocean, Earth, or climate scientists have stated similar positions on climate science. Most U.S. climate scientists are members of the American Meteorological Society (AMS) (14,000 members) and/or the American Geophysical Union (AGU) (58,000 members). Both of these societies have issued statements regarding the soundness of climate science that links human releases of greenhouse gases to recent climate change. In 2007, for example, the American Meteorological Society issued a two-page statement on climate change that includes the following:

> "Despite the uncertainties noted above, there is adequate evidence from observations and interpretations of climate simulations to conclude that the atmosphere, ocean, and land surface are warming; that humans have significantly contributed to this change; and that further climate change will continue to have important impacts on human societies, on economies, on ecosystems, and on wildlife through the 21st century and beyond."

In October 2009, the American Association for the Advancement of Science (125,000 individual and institutional members) and 17 other scientific organizations (including AMS, AGU, the American Statistical Association, the Society for Industrial and Applied Mathematics, the American Chemical Society, and the Ecological Society of America) sent a letter to members of the U.S. Senate, noting that "rigorous scientific research" and "multiple independent lines of evidence" clearly support the reality of global climate change tied to human activities. "The severity of climate change impacts is expected to increase substantially in the coming decades," the letter concluded.

In many nations the national academies of science have been asked to assess knowledge of climate science and to recommend actions for policymakers. Certain groupings of these have become powerful statements. For example, in 2005 the presidents of the national academies of the G-8 nations plus Brazil, China, and India declared jointly that "there is now strong evidence that significant global warming is occurring. . . . It is likely that most of the warming in recent decades can be attributed to human activities. . . . This warming has already led to changes in the Earth's climate. . . . The scientific understanding of climate change is now sufficiently clear to justify nations taking prompt action. It is vital that all nations identify cost-effective steps that they can take now, to contribute to substantial and long-term reduction in net global greenhouse gas emissions."

2. Can you please describe the relationship between projections of temperature increases and observations in recent years? Are the observations consistent with what would be expected because of climate change?

The first speculative projections for an increasing trend in Earth's temperature from increasing atmospheric carbon dioxide content were made more than a century ago. In the 1980s with the use of atmospheric general circulation models such projections became more realistic for climate responses both to natural climate cycles and to increasing atmospheric concentrations of greenhouse gases and aerosols. Today these models are fully coupled for atmospheric, oceanic, and biospheric processes, and organizations such as the Intergovernmental Panel on Climate Change combine these with scenarios for population and economic growth to make even more realistic projections. To properly consider the full range of climate response to socioeconomic factors that determine the rate at which greenhouse gases and aerosols are released to the atmosphere, credible projections must be given as ranges with the spread between upper and lower bounds increasing with time into the future.

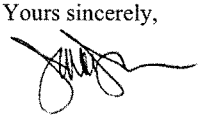
If greenhouse gas concentrations in the atmosphere increase with each successive year, will each successive year be warmer than the last? No. As we have seen over the past several decades, natural processes such as major volcanic eruptions, and natural cycles such as the eleven year solar cycle, and inherent cyclic climate phenomena such as ENSO (El Niño/La Niña) cause annual up and down wiggles in the global average temperature trend. Many studies have shown that when all of the major factors are taken into consideration the observations for Earth's annual average temperature are consistent with model projections.

3. Can you please describe how we know that greenhouse gases are contributing to observed warming?

Fundamental physics discovered in the mid-800s demonstrate the power of greenhouse gasses to trap heat, and these relationships are known with great precision. The aforementioned sophistication in climate modeling allows for quantification of the relative contributions of all the major contributors to the energy balance for Earth's atmosphere. This energy balance between the upper and lower atmosphere changes with the addition of greenhouse gases to the lower atmosphere – the lower atmosphere warms and the upper atmosphere cools. This is exactly what is being observed in balloon and satellite measurements. And this upper and lower atmospheric difference is not what would be expected if Earth's climate were changing because of a change in the intensity of solar irradiation or in cloud physics. As the climate forcing from accumulated greenhouse gases increases (today it is about ten times as large as the difference in solar intensity experienced over the eleven-year solar cycle) the roles of natural processes become less significant. When all of these known components are summed they reproduce characteristics of the current temperature for Earth's surface. It is thus clear that a major factor is not being overlooked. Moreover, if the models are run with all components except the current greenhouse gas contribution, they project an average temperature for Earth's surface today that resembles the temperatures observed early in the early 20th century.

I hope that these responses are helpful, and please let me know if you need additional clarification.

Yours sincerely,



James J. McCarthy
Alexander Agassiz Professor of
Biological Oceanography

Senator BOXER. Thank you very much.

I just want to say, on behalf of all of us, to all three of you that we are so appreciative of your testimony today. Very clear, I thought, and thought provoking.

So, we are going to start a series of questions, and then I am going to keep the record open for a couple of days. Would you all be willing to answer questions in writing? Because I know I have so many I will not have time to ask them.

Senator INHOFE. Me, too.

Senator BOXER. And so does Senator Inhofe as well as others. OK, so we will do that.

Mr. Christy, your written testimony cites a study by Anthony Watts that claims to find bias in thermometer stations' readings. Has this study been submitted to a journal for publication or been through a peer review process?

Mr. CHRISTY. Not to a journal yet.

Senator BOXER. OK. So, there has been a study, and you cite it, that there is a bias in thermometer station readings. Do you think people are lying about what they read, or are they not presenting it right? That there is a bias in thermometer station readings?

Mr. CHRISTY. Right. The study simply put the category of stations that have a lot of stuff around them in one category, and a second category of uncluttered stations, they are rural, and there is a significant difference between them.

Senator BOXER. OK.

Mr. CHRISTY. There are other things that need to be done yet.

Senator BOXER. So, who is guilty of this bias? Who is doing this? Who is making a decision that leads to a bias?

Mr. CHRISTY. I am sorry, of what?

Senator BOXER. You say that there is a bias in thermometer stations' readings.

Mr. CHRISTY. Oh.

Senator BOXER. Who is guilty of the bias? Who has the bias?

Mr. CHRISTY. If the readings of the thermometers do not take into account that clutter around the station, then there is a bias in those——

Senator BOXER. By whom?

Mr. CHRISTY. Thermometer readings are taken by the traditional surface measurements up here.

Senator BOXER. Right.

Mr. CHRISTY. Because those classification schemes have not been applied to those——

Senator BOXER. How would you fix this problem?

Mr. CHRISTY. Well, we are working on that right now.

Senator BOXER. OK.

Do you agree with that, Dr. Field, that there is a bias here?

Mr. FIELD. NOAA, the National Oceanic and Atmospheric Administration, has a number of published studies on the question of whether there any problems in the temperature record from the U.S. weather stations and their studies have consistently not been able to find any problem and consistently indicate that the stations are accurately reflecting both the underlying temperatures and the underlying temperature trends.

Senator BOXER. And has that been peer reviewed?

Mr. FIELD. Those are in the peer reviewed——

Senator BOXER. OK, so I think enough on that.

Mr. CHRISTY. OK, there are no——

Senator BOXER. If I could just finish, then you can respond.

When a study is not peer reviewed, you can understand why some of us might be skeptical. Now, Dr. Christy, have you seen this, Our Changing Climate 2012, Vulnerability and Adaptation to the Increasing Risks from Climate Change in California? It just came out. Are you familiar with it?

Mr. CHRISTY. I am familiar with previous reports. I believe I might have seen a draft of that.

Senator BOXER. This just came out yesterday. So, we will make sure you see it. I am not going to ask you specifically about what is in it. But I am going to tell you what it found. What they say is the latest science on climate changes impacts of California, dozens of scientists in over 30 peer reviewed papers. It describes various climate change impacts including increased temperatures, sea level rises, wildfire risk, and air pollution levels.

Now, you live in California, in my State. Is that correct?

Mr. CHRISTY. I am a native Californian.

Senator BOXER. All right. Where do you live now?

Mr. CHRISTY. Alabama. I am the State Climatologist.

Senator BOXER. Oh, OK. So, you are there now. Well, I want to tell you things are changing in our State if you do not know that. Just your own eyes would tell you, the type of droughts, the type of bark beetles, the types of problems that we are having. And I am asking you, do you believe——

Mr. CHRISTY. May I respond, Madam Chairman?

Senator BOXER. Do you believe that State and local governments should ignore these overwhelming scientific findings and stand idly by as the health and well-being of their citizens are harmed when such a report comes out that is peer reviewed?

And I will say to you, technical staff from all of the agencies, outside scientific experts, 26 research teams and other research groups produced 30 peer reviewed papers, and they are warning the people of California what is going to happen. And they are warning the agricultural industry and the tourist industry. Do you think we should just say let us just wait and see?

Mr. CHRISTY. I suspect they did not include my peer reviewed papers in there that do not show the changes in snowfall and Central California temperatures and so on——

Senator BOXER. So you——

Mr. CHRISTY [continuing]. Show the contamination in those peer reviewed papers. I bet they did not use those.

Senator BOXER. Well, let me just say this. You stand with about 2 or 3 percent of scientists, is that right, in your conclusions?

Mr. CHRISTY. The question, that comes from a study of 77 people. And I suspect, if I were asked the question, I would have been on the majority because the question was very milquetoast. It was, do you think climate change is occurring? Do you think the world is warming? Well, virtually everyone agrees with that, that climate change is always occurring.

Senator BOXER. So you think it is. You think it is. So, do you think that we should take action since you do not doubt that the planet is warming?

Mr. CHRISTY. Well, as a scientist I would ask the question what action do you want to take? I will test it to see if it will make a difference. And as I have done throughout all of my career——

Senator BOXER. OK, well that is a step forward that you say——

Mr. CHRISTY. Those changes will not make a difference.

Senator BOXER [continuing]. That global warming is occurring. I think that is a very important point.

So, I really do want to be a little California-centric here. We do represent 38 million people in our State.

My last question is to Dr. Field. In California in 2010, agriculture had revenues of $37.5 billion, and tourism supported nearly 900,000 jobs and $90 billion in direct spending. That is why this type of peer reviewed report is so critical to our people.

So, I am asking you if you believe, unless we can turn things around, should we expect more frequent and intensive extreme weather that could impact these types of key economic sectors?

Mr. FIELD. Thank you, Senator Boxer. As I said in my testimony, the conclusion from the latest IPCC report is really clear. A change in climate leads to change in the risks of extremes. We are already seeing increases in extremes, and we are seeing increasing risks of the kind of extremes that can lead to weather and climate disasters, the kinds of weather and climate disasters that can have profound effects on agriculture, on industry and on infrastructure.

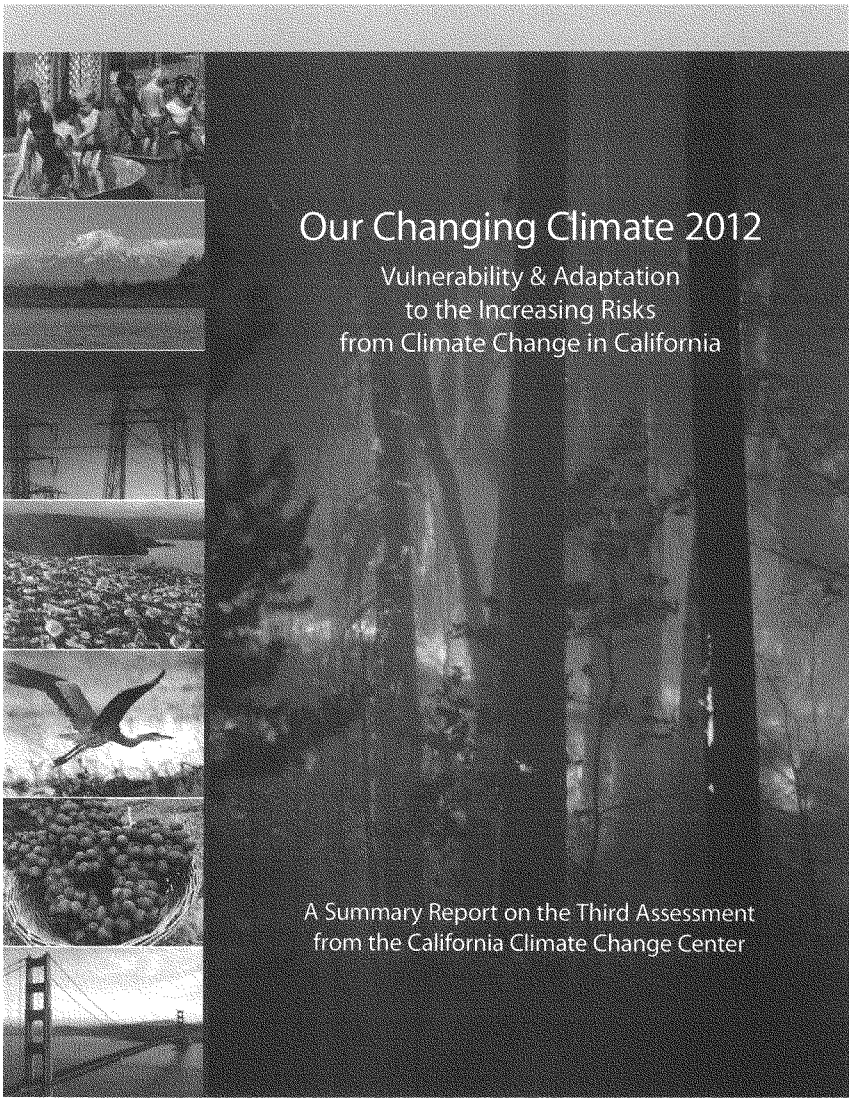
Senator BOXER. So, in just concluding my discussion with you, Doctor, I thought your testimony was clear. You said you are sure about three things. You were not sure about everything. But the three things, and I can to remember them, was higher temperatures and higher sea level, and the third one?

Mr. FIELD. We are seeing increases in the record so far of increases in extremes related to high temperatures, increases in the fraction of rainfall that is falling in the heaviest precipitation events, and increases in extreme events that are connected to high sea level, basically storm surge.

Senator BOXER. OK. Thank you very much.

Senator Inhofe.

[The referenced information follows:]


Our Changing Climate 2012
Vulnerability & Adaptation
to the Increasing Risks
from Climate Change in California
A Summary Report on the Third Assessment
from the California Climate Change Center

As the nation faces record heat, storms, drought, and wildfires, California has an advantage in its scientific understanding of climate change. A solid body of vital data is available to assist state and local leaders to better understand how climate change is affecting us now, what is in store ahead, and what we can do about it.

State-sponsored research has played a major role in recent advances in our understanding of the potential impacts of climate change on California. A first assessment, published in 2006, made clear that the level of impacts is a function of global emissions of greenhouse gases and that lower emissions can significantly reduce those impacts. The second study, released in 2009, made the case for adaptation as a necessary and urgent complement to reducing emissions.

Extended droughts have posed difficult challenges for California in recent years and could pose increasing problems with climate change.

The *2012 Vulnerability and Adaptation Study,* the State's third major assessment on climate change, is summarized here. In contrast to the previous two assessments, this one explores local and statewide vulnerabilities to climate change, highlighting opportunities for taking concrete actions to reduce climate-change impacts. This assessment examines adaptation options in regional case studies and offers insights into regulatory, legal, socioeconomic and other barriers to adaptation so that they can be addressed effectively at the local and state levels. A regional study of the nine-county San Francisco Bay Area is also included.

The third assessment, like its two predecessors, reflects a powerful collaborative process. Guided by a Steering Committee of senior technical staff from State agencies and outside scientific experts, 26 research teams from the University of California system and other research groups produced more than 30 peer-reviewed papers. They offer crucial new insights for the energy, water, agriculture, public health, coastal, transportation, and ecological resource sectors that are vital to California residents, businesses and government leaders.

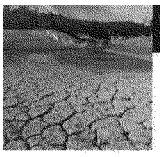
WHAT'S NEW IN 2012?

***Our Changing Climate 2012* highlights important new insights and data, using probabilistic and detailed climate projections and refined topographic, demographic and land use information.**

The findings include:

- The state's electricity system is more vulnerable than was previously understood.
- The Sacramento-San Joaquin Delta is sinking, putting levees at growing risk.
- Wind and waves, in addition to faster rising seas, will worsen coastal flooding.
- Animals and plants need connected "migration corridors" to allow them to move to more suitable habitats to avoid serious impacts.
- Native freshwater fish are particularly threatened by climate change.
- Minority and low-income communities face the greatest risks from climate change.
- There are effective ways to prepare for and manage climate change risks, but local governments face many barriers to adapting to climate change; these can be addressed so that California can continue to prosper.

Executive Order #S-3-05, signed on June 1, 2005, called for the California Environmental Protection Agency (Cal/EPA) to prepare periodic science reports on the potential impacts of climate change on the California economy. Cal/EPA entrusted the California Energy Commission and its Climate Change Center to lead this effort. The 2009 Adaptation Strategy prepared by the California Natural Resources Agency also called for a statewide vulnerability and adaptation study. This report summarizes the third of these periodic assessments, the product of a multi-institution collaboration among Cal/EPA, Natural Resources Agency, Department of Water Resources, Energy Commission, Air Resources Board, Ocean Protection Council, Department of Public Health, Department of Forestry and Fire Protection, Bay Conservation and Development Commission, Department of Transportation, Office of Environmental Health Hazard Assessment, State Coastal Conservancy, Department of Fish and Game, Department of Food and Agriculture, and State Parks. It keeps Californians apprised of new scientific developments, documents the emerging impacts of climate change, and alerts them to the increasing risks of a warming climate. Clear awareness of these risks is an important prerequisite for Californians to fully engage in efforts to reduce greenhouse gas emissions, and to prepare and plan for those impacts that cannot be avoided by emission reduction efforts.



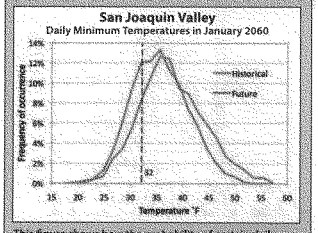
California's Changing Climate

Observed changes over the last several decades across the western United States reveal clear signals of climate change. Statewide average temperatures increased by about 1.7°F from 1895 to 2011, and warming has been greatest in the Sierra Nevada. Throughout the past century, precipitation (rain and snow) has followed the expected pattern of a largely Mediterranean climate with wet winters and dry summers, and considerable variability from year to year. No consistent trend in the overall amount of precipitation has been detected, except that a larger proportion of total precipitation is falling as rain instead of snow. In addition, during the last 35 years, the Sierra Nevada range has witnessed both the wettest and the driest years on record of more than 100 years. While intermittent droughts have been a common feature of the state's climate, evidence from tree rings and other indicators reveal that over the past 1,500 years, California has experienced dry spells that persisted for several years or even decades.

Warmer temperatures combined with long dry seasons over the last few decades have resulted in more severe wildfires. Substantially higher temperatures, more extreme wildfires, and rising sea levels are just some of the direct impacts experienced in California that can be attributed, at least partially, to climate change. Projections of California's future climate served as the basis for all studies in the third assessment.

How Likely Are Future Climate Changes?

The third assessment offers a key innovation over previous ones: *probabilistic* climate and sea-level-rise projections. The likelihood of possible climate futures represents the best estimate of what may happen under specified emissions scenarios, given current scientific understanding of the climate system. Resource managers have requested this type of information to start putting long-term planning into a risk-based framework.



This figure shows how the probability of certain daily minimum temperatures occurring will shift in 2060 (red curve) relative to their historical distribution (blue curve). It illustrates that the most frequently occurring (that is, the most likely) daily minimum temperatures will shift upward, reflecting the expected overall warming trend. Extremely cold nights with below freezing temperatures will decrease in frequency, but not completely disappear. This finding has important implications for farmers' adaptation choices as they may plant new crops that are more resilient to high temperatures but still robust in the face of occasional freezes or choose fruit trees that are less dependent on extended chill hours.

Projected Changes for the Remainder of this Century

Projecting future climate requires sophisticated computer models. Studies from the third assessment used projections from six global climate models, all run with two emissions scenarios, one lower (B1) and one higher (A2) (the same as were used in the 2009 assessment). Both the models and scenarios are well established, but future emissions may be even higher or lower depending on the choices society makes, resulting in greater or smaller climate changes. Global modeling results were then "scaled down" using two different methods to obtain regional and local information. In addition to projections of future climate, several studies in the third assessment also used several scenarios of population growth and land use policy (Business as Usual, Smart Growth, Infill, Fire Risk Avoidance, Agricultural Land Preservation, and Biodiversity Preservation) to shed light on how development patterns could make California more or less vulnerable to climate change.

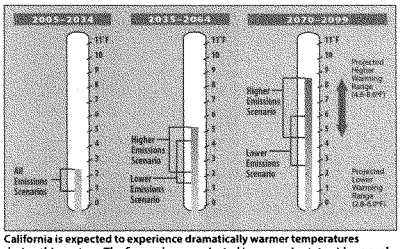
Temperatures in California will rise significantly during this century as a result of the heat-trapping gases humans release into the atmosphere. This broad conclusion holds regardless of the climate model used to project future warming. However, warming will be significantly greater with higher emissions than with lower emissions.

In the early part of this century — warming under the higher emissions scenario differs little from what is seen in the lower emissions scenario, largely because temperature increases over the next few decades are already determined by past emissions. By the latter part of this century, study findings show that the climate choices society makes today and in the coming years can have a profound impact on future conditions.

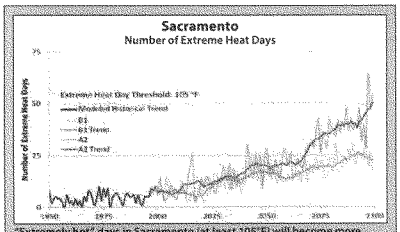
- By 2050, California is projected to warm by approximately 2.7°F above 2000 averages, a threefold increase in the rate of warming over the last century.
- By 2100, average temperatures could increase by 4.1–8.6°F, depending on emissions levels.
- Springtime warming — a critical influence on snowmelt — will be particularly pronounced.

- Summer temperatures will rise more than winter temperatures, and the increases will be greater in inland California, compared to the coast.
- Heat waves will be more frequent, hotter, and longer. There will be fewer extremely cold nights.

Projected Average Temperatures in California



California is expected to experience dramatically warmer temperatures during this century. The figure shows projected increases in statewide annual temperatures for three 30-year periods. Ranges for each emissions scenario represent results from state-of-the-art climate models.



"Extremely hot" days in Sacramento (at least 105 °F) will become more common with climate change. By the middle of this century, the number of extremely hot days could increase fivefold (up to 20 days) compared to the historical period (black curve). By the end of this century, under the higher emissions scenario (red curve), they could occur as much as ten times more often than historically. Following a lower emissions scenario (green curve) could make a big difference: Sacramento would see only half that increase.

Model projections for precipitation over California continue to show the Mediterranean pattern of wet winters and dry summers with seasonal, year-to-year, and decade-to-decade variability. For the first time, however, several of the improved climate models shift toward drier conditions by the mid-to-late 21st century in Central and, most notably, Southern California.

- By mid-century, some climate models show that the 30-year average precipitation in the San Diego region will decrease by more than 8 percent compared to historical totals, even under a lower emissions scenario.
- By late-century, all projections show drying, and half of them suggest 30-year average precipitation will decline by more than 10 percent below the historical average.

This drying trend is caused by an apparent decline in the frequency of rain and snowfall. Even in projections with relatively small or no declines in precipitation, central and southern parts of the state can be expected to be drier from the warming effects alone as the spring snowpack will melt sooner, and the moisture contained in soils will evaporate during long dry summer months.

Wildfire risk in California will increase as a result of climate change. Earlier snowmelt, higher temperatures and longer dry periods over a longer fire season will directly increase wildfire risk. Indirectly, wildfire risk will also be influenced by potential climate-related changes in vegetation and ignition potential from lightning. Human activities will continue to be the biggest factor in ignition risk. Previous research estimated that the long-term increase in fire occurrence associated with a higher emissions scenario is substantial, with increases in the number of large fires statewide ranging from 58 percent to 128 percent above historical levels by 2085. Under the same emissions scenario, estimated burned area will increase by 57 percent to 169 percent, depending on location.

New studies in the third assessment demonstrate that the distribution of where and to what degree wildfire risk increases in California will also be driven to a large extent by changes in land use and development. Modeled simulations estimate that property damage from wildfire risk could be as much as 35 percent lower if smart growth policies were adopted and followed than if there is no change in growth policies and patterns.

VULNERABILITY AND ADAPTATION DEFINED

Vulnerability, in the most general sense, is the susceptibility to harm. Vulnerability to climate change is understood as the degree to which a system is exposed to, sensitive to, and unable to cope with or adapt to the adverse effects of change, including climate variability and extremes. It is determined by the character, magnitude, and rate of climate change (the climate hazard), as well as by non-climatic characteristics of the system that might experience such a hazard. The third assessment breaks new ground in understanding the differential levels of vulnerability and related equity concerns for California, the causes of vulnerability, and the range of interventions that could be used to make a system less vulnerable and more resilient.

Adaptation to climate change involves a myriad of small and large adjustments in natural or human systems that occur in response to already experienced or expected climate changes and their impacts. The goal of adaptation is to minimize harm and take advantage of beneficial opportunities that may arise from climate change. Adaptation involves a wide range of planning and management activities that can be taken well in advance of the manifestation of impacts, or reactively, depending on the degree of preparedness and the willingness to tolerate significant risk.

Health: Many Opportunities to Reduce Social Vulnerabilities

Climate change could have major impacts on public health and well-being throughout California if adequate adaptation measures are not taken. However, many climate adaptation opportunities exist for protecting the public welfare, many of which have already proven effective. Strategic placement of cooling centers, for instance, has been clearly shown to save lives during heat waves.

Many of the gravest threats to public health in California stem from the increase of extreme conditions, principally more frequent, more intense, and longer heat waves. Particular concern centers on the increasing tendency for multiple hot days in succession, and heat waves occurring simultaneously in several regions throughout the state.

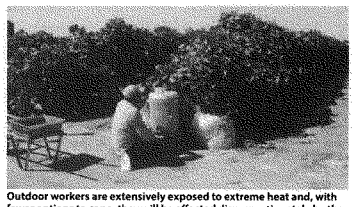
Heat waves are expected to occur more frequently and grow longer and more intense, posing particular risk to the most vulnerable.

Public health could also be affected by climate change impacts on air quality, food production, the amount and quality of water supplies, energy pricing and availability, and the spread of infectious diseases. These impacts could have potentially long-term repercussions, and the severity of their impacts depends largely on how communities and families can adapt.

Studies in the third assessment improve our understanding of Californians' vulnerability to extreme heat events and other extreme climate events. Some segments of the population are more sensitive than others and may have less ability to prepare for, cope with, or adapt to changing conditions, and will be impacted disproportionately. Understanding these characteristics (age, sex, race, education level, income, air conditioner ownership and others) can be helpful to develop and prioritize adaptation options that target those in greatest need.

For example, one study shows that mortality from various cardiovascular conditions on extremely hot days is up to 28 percent higher than normal background mortality. New studies also show elevated risks for hospitalization for stroke, diabetes, acute kidney failure, dehydration, and pneumonia for those 65 years and older, infants under 1 year of age, and African Americans. The need for emergency room visits for a variety of conditions also increase for many segments of the population, while preterm delivery is more likely for all pregnant women, especially for younger, African American and Asian American women.

The use of air conditioners significantly reduces the risk of mortality and hospitalization in times of extreme heat, which makes air conditioner ownership a useful indicator of short-term coping capacity. However, increased use of air conditioners should not be relied on as an effective long-term strategy given the risks of power outages during peak-demand periods and related higher energy demand, both of which increase costs to individual households and overall greenhouse gas emissions if the electricity comes from fossil fuel sources such as natural gas.



Outdoor workers are extensively exposed to extreme heat and, with fewer options to cope, they will be affected disproportionately by the impacts of climate change.

New studies for the San Francisco Bay Area and Fresno County find minority and poorer populations, have significantly lower access to common adaptation options for dealing with health threats from climate change, such as tree canopy for shading or car ownership to go to public cooling centers than other segments of the population. Another study finds Los Angeles to have a disproportionately large number of highly vulnerable people at risk during extreme heat.

Focus on adaptation planning is growing in public health departments across the state. Several universities and the California Department of Public Health are working together to identify climate-related health risks and those groups particularly susceptible to risks such as extreme heat and air pollution.

Higher temperatures also increase ground-level ozone levels. Furthermore, wildfires can increase particulate air pollution in the major air basins of California. Together, these consequences of climate change could offset air quality improvements that have successfully reduced dangerous ozone concentrations. Given this "climate penalty," as it is commonly called, air quality improvement efforts in many of California's air basins will need to be strengthened as temperatures increase in order to reach existing air quality goals.

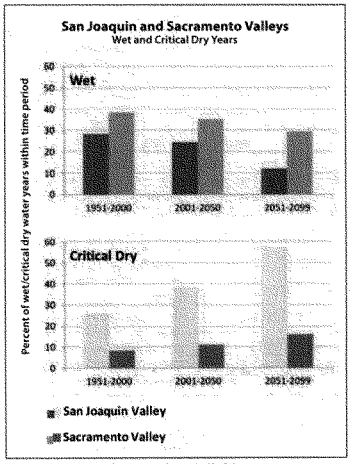
Water: Every Drop Counts

In California's semi-arid, Mediterranean climate, safe and reliable supplies of clean water are critical. The state's urgent water management challenges posed by climate change include increasing demand from a growing population as temperatures rise, earlier snowmelt and runoff, and faster-than-historical sea-level rise threatening aging coastal water infrastructure and levees in the Sacramento-San Joaquin Delta. Climate change effects on water supplies and stream flows are also expected to increase competition among urban and agricultural water users and environmental needs. Finally, increases in extreme precipitation and runoff are likely due to warmer storms and extreme "atmospheric rivers" — narrow bands over the Pacific Ocean that carry huge amounts of moisture into the state in occasional series of winter storms.

Water studies in the third assessment analyze water management options under these expected changes, and also examine the sector's sensitivity and capacity to adapt to climate change. They explore feasible adaptation strategies at the state and local levels, revealing major barriers hindering adaptation. Policies to overcome these barriers will be needed to ensure that Californians are well-prepared for climate change.

One study illustrates problems in California's water supply allocations (the amount of water that goes to different users each year) if the current allocation criteria and decision-making procedures continue to be used as the climate changes. Many water management decisions in California rely on a classification scheme of the year's water availability (distinguishing "wet," "normal," "dry," and "critically dry" years). Depending on what type of year it is, different amounts of water are allocated among the state's many users. Using the current allocation thresholds, the study projects changes in stream flow for the Sacramento and San Joaquin valleys, showing that by the latter half of the 21st century critically dry water years could occur substantially more often (8 percent more frequently in the Sacramento Valley and 32 percent more often in the San Joaquin Valley), compared to the historical period (1951-2000). During such critically dry years it is nearly impossible to satisfy the state's water needs, including those for agricultural and environmental purposes, which could affect the farm economy and endangered species. Adaptive changes in the water allocation framework could help lessen this problem.

The single most important step toward preparing for climate change in the water sector is to implement an accurate monitoring system that records water diversions.

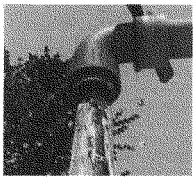


Reductions in stream flow by the latter half of the century are estimated to lead to more frequent critically dry water years, resulting in less water available to support already threatened ecosystems and species.

The third assessment also highlights notable progress in adapting water management in California, but difficult legal and political barriers impede implementation of some of the most feasible and potentially most effective strategies. Clearly, adaptation requires much more than technical solutions; societal barriers must be addressed in appropriate forums to be overcome with durable commitments.

Another study, focusing on legal and institutional barriers to adaptation suggests that climate change will exacerbate ongoing conflicts over water by increasing demand and decreasing supply. The study concludes that the most important step toward preparing for climate change would be to implement and enforce an accurate monitoring system that records who is diverting water, in what quantities, and when. This would significantly improve decision-making compared to the current water management in which groundwater is essentially unmanaged.

INFORM: A decade of collaboration between scientists and California water managers has led to the development of a probabilistic-based decision-support software, called INFORM (Integrated Forecast and Reservoir Management), that has shown demonstrable success in increasing water supply availability and hydropower generation from the state's largest reservoirs in Northern California, while still protecting the public from flooding. These reservoirs represent about 68 percent of the total storage capacity in the Sacramento and San Joaquin region, and about two-thirds of the state's drinking water. Some of the world's most productive farmlands also depend on that water for irrigation. A new study tests this probabilistic forecasting system as a tool to support water utilities in their management efforts. To fully implement such a system in California, major obstacles would have to be overcome, including challenges in interagency coordination and cooperation at the local level, operational rules, norms of professional behavior, and legal barriers at the federal level, which may require Congressional action.



Smaller water agencies that do not import water but instead rely mostly on local sources can adapt to climate change by developing groundwater drought reserves to buffer against shortages.

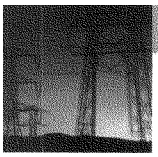
For water districts where imported water is either limited or unavailable, and that rely on local sources for water, groundwater reserves are an especially important adaptation strategy in the face of increasing risk of drought. California has always relied heavily on its groundwater when surface water supplies have dwindled during droughts. One study of smaller water districts in Central and Northern California show that regulatory constraints on using surface water supplies, along with stakeholder and agency leadership, were key motivators to move toward more sustainable groundwater management and the establishment of reserves. Such efforts support adaptive water management at the local level.

Delta Subsidence and Levee Safety

The Sacramento-San Joaquin Delta is a critical freshwater resource for California and its reliability depends significantly upon the integrity of the earthen levees protecting dozens of Delta islands. These levees protect not only much of the state's water supply, but also important energy infrastructure such as underground natural gas storage fields, pipelines and transmission lines. Farmland, homes, and endangered species are also at risk. In the event of a levee failure — whether as a result of an earthquake or overtopping during storms — brackish water would fill the Delta lowlands and rapidly degrade freshwater quality and supplies and threaten the other assets. Consequently, it is critical to monitor the relationship between levee elevations and sea level. The island interiors have sunk from elevations near sea level at the end of the 1800s to current elevations as much as 15 feet below sea level. Sinking (or "subsidence") of delta islands has been attributed historically to compaction and loss of peat soils drained for agricultural purposes. A new study using satellite radar data finds that in addition to localized subsidence, the entire Delta may be sinking. Land subsidence together with rising sea levels may cause water levels to reach dangerous levels as early as 2050. However, ongoing monitoring of levee heights may provide sufficient advance notice to prioritize and take necessary protective measures.

More than 1,300 miles of levees currently protect islands in the Sacramento-San Joaquin River Delta. As the climate changes, altered river flows, higher sea levels, and changes in wind are likely to increase the risk of levee failure. In addition, the entire Delta region appears to be sinking, which may cause many levees to fall below safety design thresholds as early as 2050 unless additional protective measures are taken.

Difficult legal and political barriers impede implementing the most effective adaptation strategies.



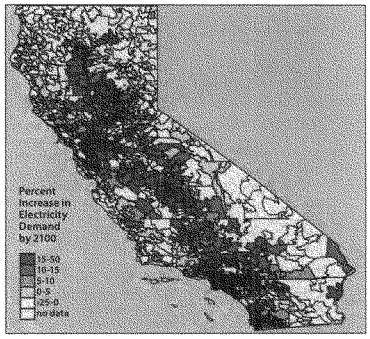
Energy: Meeting Growing Demand in a Warming World

Increases in average temperature and higher frequency of extreme heat events combined with new residential development across the state will drive up the demand for cooling in summertime. This growing demand will only partially be offset by decreased heating needs in the wintertime and improved energy efficiency. Californians derive about 15 percent of their electricity from hydropower with more than half of this energy generation occurring above 1,000 feet elevation in relatively small systems. Hydroelectricity is a premium asset during the peak-demand summer months. Past studies have already shown that this hydropower generation is declining, and it is expected to decrease more substantially as climate change progresses due to reduced snowpack, earlier runoff, and higher rates of evaporation.

Energy demand is increasing. The third assessment confirms that climate change will increase demand for cooling in the increasingly hot and longer summer season and decrease demand for heating in the cooler season. California's residential sector uses relatively little electricity for heating, and it is therefore expected that the demand for electricity will increase as households operate existing air conditioners more frequently. It is also expected that in many regions where currently there are few air conditioners, more will be installed. Using household level data to estimate how electricity consumption responds to hotter weather, researchers can project increases in annual electricity consumption at the ZIP code level. Their study finds that predominantly non-minority and wealthier ZIP codes are projected to experience smaller increases in energy consumption, while ZIP codes with a higher share of Latino and lower-income residents are projected to experience larger increases in energy use. This may in part be driven by the fact that wealthier people more often live near the coast where cooler ocean breezes reduce the amount of warming. In the near term, higher temperatures in the next decade could increase demand by up to 1 Gigawatt during hot summer months — a substantial amount that would require the construction of one large new power plant in California or the purchase of costly peak power from external sources.

Climate change will increase demand for cooling in the increasingly hot and longer summer season.

Increase in Electricity Demand by the End of this Century
(higher emissions scenario, compared to historical conditions, in percent)



Higher summer temperatures will notably increase the annual household electricity consumption for air conditioning (by ZIP code). Because inland areas will warm more, and are often home to less wealthy populations, energy use will grow most in the hottest areas where those who can least afford it reside.

Climate warming will decrease hydropower generation mostly in the summer months when hydropower generation is needed most to meet peak demand.

Energy supply from hydropower is generated in more than 150 high-elevation hydropower plants (above 1,000 feet). These units supply about 75 percent of all the hydropower produced in California. The small size of the high-elevation hydropower reservoirs allows little flexibility in operations and might make high-elevation hydropower plants more vulnerable to climate change and reduced snowpack. Researchers have developed a multi-purpose water resources management simulation model for the western slope of the Sierra, from the Feather River watershed in the north to the Kern River watershed in the south. Their study finds — importantly — that electricity generation will be reduced substantially in the summer when hydropower generation is needed most to meet peak demand.

For low-elevation hydropower, typically associated with larger reservoirs, there are ways to reduce climate change impacts using modern hydrological forecasting tools. The INFORM project demonstrates that probabilistic hydrologic forecasting could substantially reduce the negative impacts of climate change on water supply, hydropower generation, revenues, and flood protection. Managers of high-elevation hydropower plants have some, but generally less, flexibility to manage water adaptively. For example, changing the operating rules of the reservoirs can help minimize revenue losses in case of a drier, warmer climate with lower water flows. If hydropower plants were to generate 20 percent less power annually in a drier, hotter climate, they could see revenue losses of 8 percent, compared to current average revenues. While the high-elevation hydropower system can benefit from additional storage and generation capacities, more studies are needed to determine whether the expected increase in revenues will outweigh the expected economic and environmental costs of potential energy and storage capacity expansions.

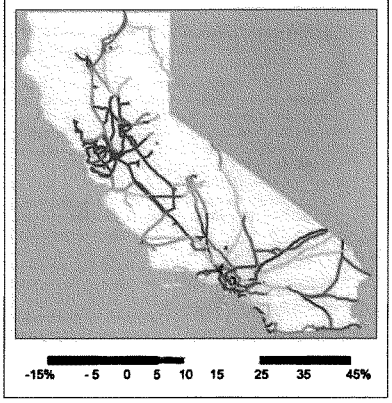
High-elevation hydropower is particularly vulnerable to climate change and reduced snowpack.

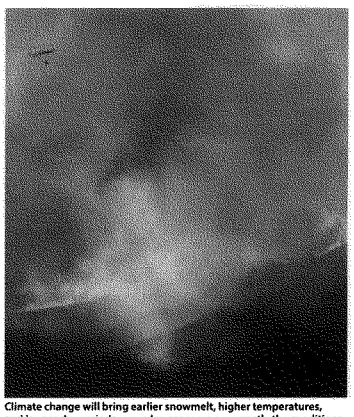
Transmission of electricity will also be affected by climate change. In addition to reduced efficiency in the electricity generation process at natural gas plants, reduced hydropower generation, losses at substations, and increasing demand during the hottest periods (resulting in more than 17 Gigawatts or 38 percent of additional capacity needed by 2100 due to higher temperatures alone), transmission lines lose 7 percent to 8 percent of transmitting capacity in high temperatures while needing to transport greater loads. This means that more electricity needs to be produced to make up for the loss in capacity and the growing demand.

Key electricity transmission corridors are increasingly vulnerable to increased frequency of wildfire.

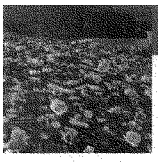
In addition, key transmission corridors are vulnerable to increased frequency of wildfire. For example, one study in the third assessment finds a 40 percent increase in the probability of wildfire exposure for some major transmission lines, including the transmission line bringing hydropower from the Pacific Northwest into California during peak demand periods. Other key transmission lines at high risk bring power to the Los Angeles Metropolitan Area. These risks can be reduced by introducing more locally produced and distributed electricity.

Wildfire Risk to Electricity Transmission Lines
(Changing probability in fire risk by end of century compared to 1961-1990, higher emissions scenario)





Climate change will bring earlier snowmelt, higher temperatures, and longer dry periods over a longer season — exactly the conditions that increase the risk of wildfire. With more development and critical transmission lines at risk, property damages and firefighting costs could rise dramatically.



Coasts: Faster Rising Seas

Coastal counties in California are home to about 32 million people, generating billions in revenues from industry, shipping, tourism and other economic activities that support millions of jobs. Every California coastal community will experience the impacts of sea-level rise in the decades ahead, and some are already feeling the effects. Previous research estimated that property worth $50 billion and at least 260,000 people are currently located in areas vulnerable to a 100-year coastal flood (a flood that has a 1 percent chance of occurring in any single year). If population and development were kept at today's levels, a 100-year flood in 2100, after a 55-inch sea-level rise, would put at risk 480,000 people and $100 billion of property (in 2000 dollars) along San Francisco Bay and the open coast.

As early as 2050, today's 100-year storm event could strike annually on average as a result of sea-level rise.

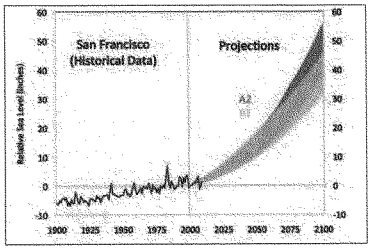
A wide range of critical infrastructure — such as schools, roads, hospitals, emergency facilities, wastewater treatment plants, airports, ports, and energy facilities — will also be at increased risk of flooding. Although reducing heat-trapping greenhouse gas emissions can reduce the magnitude of sea-level rise over the very long term (hundreds of years), adaptation is the only way to deal with the impacts from sea-level rise that cannot be avoided.

Sea level along California's coastline has risen about seven inches in the last century. This rate is expected to accelerate considerably in the future. Assuming that sea-level changes along the California coast continue to track global trends, sea level along the state's coastline in 2050 could be 10-18 inches higher than in 2000, and 31-55 inches higher by the end of this century. This represents a four- to eightfold increase in the rate of sea-level rise over that observed in the last century.

Besides global warming, sea level is driven even higher during certain times — such as when high tides coincide with winter storms or during El Niño events. Past experience shows that such extreme high sea levels, combined with high winds and big waves running up the beach, can cause severe flooding and erosion of beaches and cliffs. While wave extremes may not appreciably increase over the course of this century, higher sea levels ensure that waves and storms will cause more erosion damage than in the past.

The third assessment refines our understanding of the extent and timing of flooding from projected sea-level rise, showing that wind and waves could make coastal storms more damaging. As early as 2050, given current projections of sea-level rise, today's 100-year storm could occur once every year. Moreover, the risk from flooding in coastal counties is unevenly distributed with low-income and minority communities particularly vulnerable in some areas.

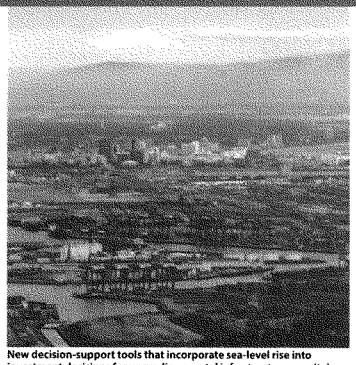
Sea-level rise: Historical Trend and Future Projections
1900-2100 under a Higher (A2) and Lower (B1) Emissions Scenario



Sea level along the California coast could be 10-18 inches higher in 2050 than in 2000, and 31-55 inches higher by the end of this century (depending on the emissions scenario). This represents a fourfold to eightfold increase in the rate of sea-level rise compared to what has been experienced historically.

More sophisticated mapping and modeling techniques used in the San Francisco Bay have vastly improved our ability to predict the location and extent of flooding by taking into account the flow of water and the vertical height of structures such as roads, levees, and seawalls. In some instances, this new technique reveals that fewer areas might be inundated in the future if these protective structures are maintained and other still vulnerable areas can be more clearly identified. In addition to risks of property damage, coastal storms combined with higher sea levels could have devastating effects on the ability of emergency responders to reach remote communities during disasters. Using more sophisticated maps of flood risk, scientists estimate that during a 100-year flood with just 16 inches of sea-level rise, 23 emergency responder fire stations in the

Risk from flooding in coastal counties is unevenly distributed, with low-income and minority communities particularly vulnerable in some areas.



New decision-support tools that incorporate sea-level rise into investment decisions for upgrading coastal infrastructure are vital to California's economy.

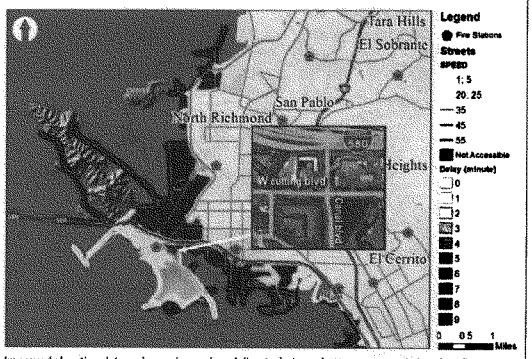
region could become inaccessible. Findings also show how extreme events with higher sea levels could lead to significantly longer driving times as some transportation corridors could be cut off. Adaptation measures that protect or relocate critical infrastructure, while expensive, could reduce the vulnerability of the transportation sector. Other coastal regions such as Los Angeles and Santa Barbara could similarly benefit from such advanced mapping tools.

Sea-level rise and associated coastal flooding are expected to put critical infrastructure at risk, including ports that support the economy and provide critical goods to the state and nation. How to alter port infrastructure to prepare for serious risks with low or unknown probability is a major challenge because substantial financial investments are at stake. The optimal time to alter infrastructure is during scheduled upgrades. One study in the third assessment applies a new approach to facilitate decision-making by port authorities in Los Angeles by incorporating low-probability high-impact uncertainties into planning for infrastructure upgrades. It shows that the costs of upgrading infrastructure for extreme sea-level rise at this time are too high to warrant incorporation for most of the facilities analyzed. However, the approach proves useful in helping the port authority to use sea-level rise scenarios to determine the most robust course of action in a scientifically informed way. Future infrastructure placement and upgrade decisions in Los Angeles and elsewhere will benefit from using a similar approach.

A statewide survey of coastal managers in 2011 updates a previous effort that tracked progress on adaptation in coastal California. Findings show a remarkable increase in awareness, concern, and understanding about climate change impacts and the need to adapt. But planning for the future with climate change in mind is still in the very early stages. The most familiar strategies to deal with sea-level rise are those that were used historically such as "coastal armoring," while more innovative approaches such as "planned retreat" and integrating natural ecosystems as buffers against sea-level rise and storms ("ecosystem-based adaptation") are less familiar. Findings are in line with results of a detailed set of case studies of local government and regional adaptation processes in San Francisco Bay, which show that communities are just beginning adaptation planning. Despite economic constraints and other obstacles, coastal communities with strong leadership and commitment to collaboration and communication are making important progress in preparing for the future.

Flooding Threatens Critical Transportation Routes

Emergency Response Delays Increase Vulnerability for Local Residents



Improved elevation data and mapping and modeling techniques better capture existing shoreline protection structures and more clearly identify the most vulnerable transportation access and connection points. In Richmond, emergency response could be delayed (dark orange, indicating delays up to nine minutes) or become unavailable (black) due to roadway flooding as shown for one area of the city in the inset aerial photo.

Ecosystems: Changing Landscapes, Vulnerable Species, More Fires

California is one of the most ecologically diverse places in the world. The state's ecosystems also provide a wide spectrum of goods and services supporting the economy of California and human well-being, including fresh water, fertile soil, biological and genetic diversity, crop pollination, carbon storage, climate stabilization, and recreational opportunities. All of these values and benefits can be lost when species are lost or ecosystems become unhealthy and fragmented, or burn in wildfires.

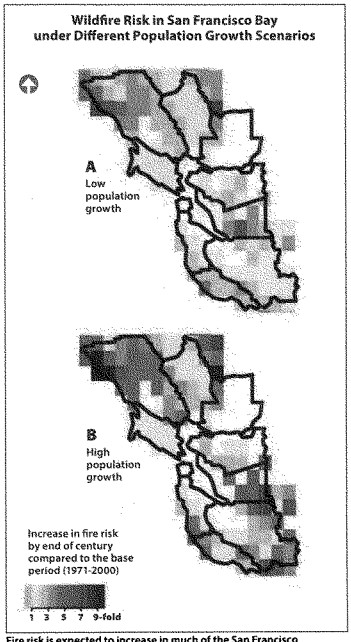
Studies from the third assessment refine estimates of future wildfires, this time also considering various population growth scenarios. Several studies have helped generate a better understanding of how California's ecosystems are sensitive to climate change and how natural resource managers can assist in their adaptation.

An increase in the frequency and extent of wildfires due to a hotter and possibly drier future, leading to significant property damage to homes, was already established in previous studies. The extent of the increased economic loss from fire, however, also depends on population growth and development in fire-prone areas. Studies from the third assessment refine the estimates by exploring the varied effects of emissions scenarios, population growth, and exposure at the wildland–urban interface.

Wildfire risk is expected to increase — even under a lower emissions scenario — almost everywhere in the state. By 2050, annual fire damage could be between $200 million and $2.5 billion, largely driven by differences in human development at the wildland–urban interface.

Even with lower emission levels, wildfire risk still increases throughout most of the state. But the extent to which wildfire risk increases depends also on the way human development advances at the wildland–urban interface. In some instances, this factor is even more important than climate change alone. The most extreme increases in residential fire risks result from a combination of high-growth/high-sprawl/warmer-drier climate change scenarios, especially in San Francisco Bay and Southern California counties.

Improving knowledge of California's species and ecosystems provides a deeper understanding of the services they provide to society. Studies in the third assessment improve this understanding, especially which species and habitats are most exposed, sensitive, and able to adapt to climate change over time. They also reveal adaptation options specifically geared toward addressing underlying vulnerabilities, thus identifying and helping to prioritize management actions.



Fire risk is expected to increase in much of the San Francisco Bay Area. Population growth will be a major factor, even if little changes at the wildland–urban interface. Yellow hues indicate smaller increases in fire risk, and darker reds and browns indicate greater increases compared to the risk during the base period (1971-2000). Green represents reductions in risk, white indicates areas that were not modeled.

Several studies focus on how vegetation could shift with climate change and the capacity of species to migrate and keep up with geographic changes. We now know that

Identifying migration corridors is critically important: As species try to keep pace with changing climate conditions, their chance of survival is greater when they can reach more suitable habitat.

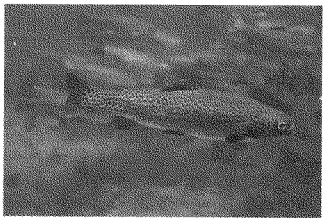
ecological impacts of climate change could be more severe than anticipated if species are unable to overcome physical barriers (such as human settlements) to migrate to areas with suitable climatic conditions. Identifying migration corridors has important practical applications for land use planning. Areas that may not be of particular ecological importance at present and that may be considered for development could play a key role in the preservation of ecologically rich conditions in California as the climate changes.

To the extent that there are no suitable habitats nearby that species can reach on their own, managers may need to assist them in relocating to fitting habitats elsewhere.

Another study uses 100 years of historical observations of species behavior to understand what could happen in the future. Findings show that climate is changing conditions so rapidly that some vegetation cannot keep pace. In fact, some climates that currently still exist (such as alpine climates) could disappear entirely in the future, while other regional climates (such as desert climates) could expand significantly, resulting in some species losing their habitats and others expanding theirs. To the extent that there are no similar suitable habitats nearby that species can reach on their own, managers may need to assist them in relocating to new suitable environments.

California's Native Freshwater Fish

Many of California's 121 native freshwater fish species are already in decline and are particularly vulnerable to climate change, with 83 percent being at high risk of extinction as the climate changes. Commercially important species, such as coho salmon and steelhead trout, are particularly at risk for extinction because they require cold water below 72°F. In contrast, the 43 non-native species examined appeared to fare much better with many thriving and expanding their range, and only 19 percent falling into the high-vulnerability category. Managing invasive species, providing shading along river banks, and reducing other stresses on freshwater fish are among the most important adaptation options.

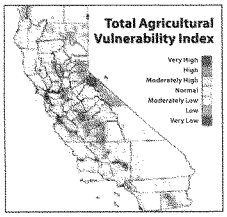


Agriculture: Vulnerable but Adaptive

Agriculture in California generates more than $30 billion per year, the highest crop value in the nation, provides more than 1 million jobs, and serves as an important source of the nation's food supply. The sector is already under stress from competing and growing urban and environmental water demands and continuing development on agricultural land. Climate change is expected to exacerbate stresses on the agricultural sector. Changes in temperature and water availability — annual and seasonal shifts as well as extremes — affect both crop yield and quality, making the sector highly sensitive to climate change.

California is one of the nation's largest producers of a diverse set of crops. While many factors will determine the choice of crops and production costs, many experts believe costs to consumers could go up.

Indirect impacts will also take a toll, including possible further decreases of pollinators and increases of pests and disease. Studies in previous assessments established that many impacts on perennials (such as peaches, strawberries, and almonds) vary by crop, while nearly all annual crops (such as wheat and sunflowers) are expected to decline under climate change. Agriculture will continue to be an important economic sector but some losses will be incurred and the ultimate impacts will be a function of how effectively farmers adopt adaptation measures.



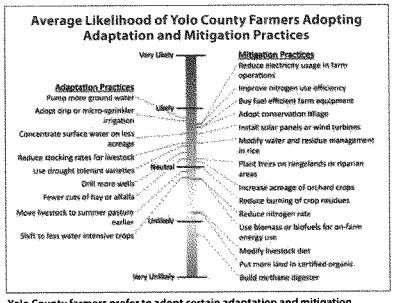
Agriculture varies in its vulnerability to climate change. The map shows a composite index of vulnerability revealing the Sacramento-San Joaquin Delta, Salinas Valley, Imperial Valley, and the corridor between Merced and Fresno as particularly vulnerable. Underlying factors vary among regions, including differences in climate, crops, land use and socioeconomic factors.

Planning for agricultural responses to climate change in California involves consideration of many factors — biological, environmental and socioeconomic — that influence the sector's vulnerability and resilience. The third assessment advances the understanding of vulnerability at the state and regional levels, reports on farmers' perspectives on adaptation, and highlights potential benefits of innovative adaptation practices that simultaneously contribute to reducing greenhouse gas emissions. Results point to the need for crop-specific and place-based approaches to reducing farmers' vulnerability to climate change.

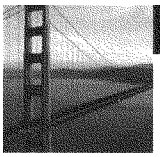
Innovative practices illustrate mitigation and adaptation opportunities for the agricultural sector. The third assessment highlights farmers' interest in adopting certain adaptation and mitigation options. Some management practices simultaneously achieve co-benefits for both, such as irrigation technologies that provide a reliable water supply and also reduce emissions of nitrous oxide (a greenhouse gas). Other examples include soil carbon storage, renewable energy, and crop diversification in local farming systems. Overall, adopting adaptation strategies that work for specific locations and crops will increase farmers' capacity to manage changes while addressing the needs of natural resources and social issues such as farm labor and urbanization pressure.

Some agricultural management practices simultaneously achieve co-benefits for climate change adaptation and mitigation.

One study of Yolo County farmers reveals that growers worry most about a potentially hotter and drier future even though they show little awareness of the industry's vulnerability to climate change. Several strategies show high potential for increasing the sector's resilience, but these require investment and training for farmers.



Yolo County farmers prefer to adopt certain adaptation and mitigation practices over others. However, preferable options may not necessarily be the most effective or reliable over the long term, or may have negative side effects, such as pumping more ground water in times of drought.



San Francisco Bay: A Regional Focus

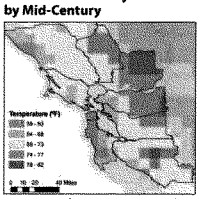
The third assessment breaks new ground by explicitly including a regional focus. Eleven studies focus exclusively on the San Francisco Bay Area to integrate findings across sectors and to better support adaptation planning and implementation processes precisely at the level at which most adaptation decisions are made: locally.

The San Francisco Bay Area was selected because of its economic importance to the state, coverage of both rural and urbanized land uses, its diverse coastal and inland geography, and the many climate change risks the nine-county region will experience simultaneously. Also important was the willingness and high interest of regional decision-makers (the Joint Policy Committee) in policy- and management-relevant scientific information. Key climate vulnerabilities were examined for coastal areas, public health, ecosystems, agriculture, wildfire, transportation and energy infrastructure, and water resources.

Local governments face considerable barriers to adaptation. One study offers an in-depth analysis of adaptation initiatives to date in the San Francisco Bay Area (Marin and Santa Clara Counties, the cities of San Francisco and Hayward, and the Bay Area-wide adaptation effort under the Joint Policy Committee). The study reveals institutional and governance issues as the most important barriers for local governments, followed by attitudinal issues and economic hurdles, even in wealthy communities. The study shows that while many issues can be addressed locally, state and federal assistance is needed to ensure that communities can adequately prepare for the impacts of climate change.

Other studies reveal how differences in social vulnerability make for inequality of impacts. Such studies provide crucial information to local governments for determining where to focus limited resources for adaptive risk management. Equipped with such locally specific information and a history of innovative leadership, the San Francisco Bay Area will be in a good position to create a safe and prosperous future.

Summer Temperatures in San Francisco Bay Area by Mid-Century



Projections of temperature across the Bay Area (under the higher emissions scenario) largely reflect differences in topography and distance from the ocean.

Our Resilient Future

Strengthening mitigation: California has been a global and national leader in developing solutions to energy security and climate change. The state's landmark Global Warming Solutions Act (AB 32, passed in 2006) established greenhouse gas emission reduction targets for 2020. A separate Executive Order established a goal for even more dramatic reductions (80 percent below 1990 levels) by 2050 and beyond.

A study in the third assessment shows both the challenges for the existing energy system emerging from climate change and the possibilities for moving toward clean, renewable energy and more robust, distributed electricity production and transmission. Given the State's commitment to reducing emissions, the energy sector is changing rapidly. This presents both challenges and tremendous opportunities to change the sector to be more resilient to climate change. Solar photo-voltaic and wind energy are less vulnerable than conventional power plants to climate change, and these renewable sources use much less water than fossil fuel or nuclear power plants. These are important advantages in light of projected climate changes for California and the western United States.

Advancing adaptation: At the same time, the State has recognized the need to adapt to climate change impacts that can no longer be avoided. Currently, the State is developing its second adaptation strategy, acknowledging the steady progress made since the first one in 2009 and recognizing the enormous challenges ahead. The strategy will need to be updated periodically in the future. The many adaptation planning efforts underway in virtually every State agency, in local communities such as Chula Vista, San Diego, Los Angeles, Santa Barbara, Santa Cruz, San Francisco, Hayward, Marin County, and others, as well as in private businesses suggest that CEOs, elected officials, planners, and resource managers understand the reality that California and the world is facing.

In fact, the latest climate science makes clear that State, national and global efforts to mitigate climate change must be accelerated to limit global warming to levels that do not endanger basic life-support systems and human well-being. Success in mitigation will keep climate change within the bounds that allow ecosystems and society to adapt without major disruptions. Further advances in integrated climate change science can inform California's and the world's climate choices and help ensure a resilient future.

Steering Committee for the Third Assessment:

Daniel Cayan, Susanne Moser, Michael Hanemann, John Andrew, Sarah Pittiglio, and Guido Franco

Authors of *Our Changing Climate 2012*:

Susanne Moser, Julia Ekstrom, and Guido Franco

(Additional help and reviews were provided by Dan Cayan, John Andrews, Mark Wilson, Bart Ostro, Alison apRoberts, Lauren Oliver, Ana Toscano, Janna Franks, Mary Tyree, Myoung-Ae Jones, and Laura Myers Design)

Photo credits (listed sequentially by page, top to bottom, left to right, at first appearance only): [C] Centers for Disease Prevention and Control (Jim Gathany); California Parks; California Department of Water Resources (DWR); National Park Service (NPS); DWR; US Department of Agriculture, Agricultural Research Service (Bob Nichols); Wikimedia Commons (Rich Niewiroski Jr.); California Emergency Management Agency (Robert A. Eplett); [1] DWR; [2] Natural Resources Conservation Service (Tim McCabe); [4] Rani McLean; Center for Disease Prevention and Control (Amanda Mills); [6] DWR; Wikimedia Commons ("Anynobody"); DWR; [7] DWR; [8] Federal Emergency Management Agency (Andrea Booher); [10] Wikimedia Commons (Nick C. Print); [11] US Fish & Wildlife Service (USFS); [12] US Geological Survey; USFS; California Department of Public Health, Network for a Healthy California; [BC] Department of Energy/National Renewable Energy Laboratory (Warren Gretz).

Thank you! More than 120 researchers from California research institutions and others participated in the 2012 California Vulnerability and Adaptation Study. Space limitations allow only the principal researchers to be listed here, in alphabetical order, but the efforts of each and every researcher are gratefully acknowledged.

David D. Ackerly, University of California, Berkeley
Maximilian Auffhammer, University of California, Berkeley
Rupa Basu, California Office of Environmental Health Hazard Assessment, Oakland
Greg S. Biging, University of California, Berkeley
Peter D. Bromirski, University of California, San Diego
Benjamin A. Brooks, University of Hawaii
Benjamin P. Bryant, Pardee RAND Graduate School, Santa Monica
Daniel R. Cayan, University of California, San Diego
Rebecca Chaplin-Kramer, Stanford University, Palo Alto
Heather Cooley, Pacific Institute, Oakland
William Cornwell, University of California, Berkeley; Vrije University, Netherlands
Larry Dale, Lawrence Berkeley National Laboratory, Berkeley
Julia Ekstrom, University of California, Berkeley
Daniel Farber, University of California, Berkeley
Catalina Garzon, Pacific Institute, Oakland
Konstantine P. Georgakakos, Hydrologic Research Center, San Diego
Jeffery Greenblatt, Lawrence Berkeley National Laboratory, Berkeley
Gary Griggs, University of California, Santa Cruz
Marion Guegan, Lund University, Sweden
Van R. Haden, University of California, Davis
Michael Hanemann, University of California, Berkeley
Lee Hannah, University of California, Santa Barbara
Matthew Heberger, Pacific Institute, Oakland
Louise Jackson, University of California, Davis
Michael Jerrett, University of California, Berkeley
Meg Krawchuk, University of California, Berkeley
Deborah Lambe, University of California, Berkeley
Ruth Langridge, University of California, Santa Cruz
Robert Lempert, RAND Corporation, Santa Monica
Jay R. Lund, University of California, Davis
Kaveh Madani, University of California, Riverside; University of Central Florida, Orlando
Sara Moore, University of California, Santa Cruz
Craig Moritz, University of California, Berkeley
Max Moritz, University of California, Berkeley
Susanne C. Moser, Susanne Moser Research & Consulting, Santa Cruz; Stanford University, Palo Alto
Peter B. Moyle, University of California, Davis
Sarah E. Null, University of California, Davis
Bart Ostro, California Office of Environmental Health Hazard Assessment, Sacramento
John D. Radke, University of California, Berkeley
David E. Rheinheimer, University of California, Davis
Maria Santos, University of California, Berkeley
Jayant Sathaye, Lawrence Berkeley National Laboratory, Berkeley
William S. Sicke, University of California, Davis; Jason G. Su, University of California, Berkeley
James H. Thorne, University of California, Davis
Mary Tyree, University of California, San Diego
Joshua H. Viers, University of California, Davis
Anthony L. Westerling, University of California, Merced
Erika Zavaleta, University of California, Santa Cruz

Support was provided in part by the California Energy Commission and the Natural Resources Agency. The material contained in this document does not necessarily represent the views of the funding agencies or the State of California.

July 2012 / CEC-500-2012-007

Senator INHOFE. Thank you, Madam Chairman.

Let me, first of all, ask unanimous consent to place into the record an article that completely discredits the Perkins Institute article that was referred to. It is from the New York Times, entitled Number of Green Jobs Fails to Live up to Promises. Part of the record, please.

Senator BOXER. It was the Brookings Institute, not the Perkins Institute, but I will put it into the record.

[The referenced information was not received at time of print.]

Senator INHOFE. The second thing I want to do, I think everyone on the other side of the aisle referred to Richard Muller, and I think it is important that we realize that perhaps he has been somewhat discredited. Roger Pelkey, Sr., said it certainly appears that Richard Muller is an attention getter which he has succeeded at, unfortunately he has demonstrated a remarkable lack of knowledge concerning the uncertainties in qualifying the actual long-term surface temperature trend, as well as a serious incomplete knowledge of the climate facts. The bigger issue is how the New York Times let itself be conned into running Muller's op-ed.

Second, the one who is the darling of everybody to the left of me right now, Michael Mann, he said it seems in the end quite sadly that it is all really about Richard Muller's self-aggrandizement.

Senator BOXER. We will put that into the record.

Senator INHOFE. Very good, very good.

Now, let me just briefly, because there is not going to be enough time to get to everything I would like to, but as I mentioned early in my opening statement there is a confidence problem, crisis, in the U.N. IPCC. A lot of people are not even using that anymore.

Yet it is important because, if you remember, as the Obama administration said, the IPCC is the gold standard. So, we need to recognize what has happened, and I would only ask, I think everyone on this panel has said some things that it needs reform, and a lot of reform efforts have taken place.

In my opening statement, we talk about the discrediting of the IPCC which I have been talking about, quite frankly, for 10 years. So I would ask you, Dr. Christy, do you think now that the changes that you are have seen, that are in the process of being made, are going to clean up the credibility of the IPCC?

Mr. CHRISTY. Well, I have not seen the 2013 report yet. But I do not suspect much will change. When you collect a bunch of people who have the same, pretty much the same view, about climate change and exclude those who have different views, you will get the answer you want.

Senator INHOFE. Yes. And I think you have probably looked on my Web site and some of the talks that I have made on the floor where we have actually had scientists calling in and saying how they were rejected from the process because of their views. So, I think it has been biased all along from the very beginning.

A lot of people believe that today's hearing is an effort to capitalize on the recent weather events of the summer in an attempt to reignite the global warming hysteria. And I would note that when I—put the igloo up. Now, to the right of the igloo is a beautiful family. Those are six of my—I have 20 kids and grandkids, those are six of them. They were up here stranded in Washington

a couple of years ago because of extreme weather, and all of the airports were closed.

But at that time I never said or implied anything, just because it was a very cold winter, that that had anything to do with discrediting global warming. And so, I think it is important that if one scientist who was interviewed in response to the igloo my family built called attempts to link single weather events to longer term climate patterns complete, ignorant nonsense. Nevertheless, there have been those on the outside who have tried to say this is the pattern.

I do not think that there is, I have said this on the Senate floor, I believe I would say to my good friend, Senator Sanders, that one area where all scientists should agree, that one pattern, or a cluster pattern, is not indicative of anthropogenic gas, global warming. And I believe that to be true.

So, Dr. Christy, do you have anything to say about this? Because this is what is going on right now. As a matter of fact, in an interview in my State of Oklahoma, they are saying, we are having very hot weather. My wife even called in a comment on that when I was on the floor with Senator Sanders. So I would like to have you kind of explain what your feeling is concerning weather versus climate.

Mr. CHRISTY. I think the clearest way to answer that is to look at a lot of stations and see when their record highs occur. And if you look again at my written testimony, Figure 1.3, it is very clear that our record extreme high temperatures are not increasing, that decades in the past had many more when the stations are consistently used. Not just stations with 30 years of record, stations with 100 years of record that picked up those heat waves of the 1920s and 1930s.

Senator INHOFE. Well, let me just ask you another question. On the floor of the Senate on Monday I was doing this, and I have done it so much I can do it from memory, but going through the last hundred or so years, from 1895 to 1925 we had a period of about 30 years where it was— people were saying another ice age is coming; we are all going to die. And that when hysteria set in.

Then from 1925 to 1945 we went through a warming period, and that is when the phrase global warming was actually coined, at that time. Then from 1945 to 1975 we went into another ice age, so-called. That is when the National Academy of Sciences said.

No, you went an extra minute and a half so I am doing the same thing.

Senator BOXER. I know, you are asking a question——

Senator INHOFE. I am asking a question. I will get an answer in a minute.

And the interesting thing about all of these things, of going through this, is that no one disagrees with the fact that the greatest surge in the release of CO_2 occurred after World War II, around 1945. Why did that precipitate a 30-year ice age as opposed to a warming period?

Mr. CHRISTY. Well, about that I will say this. Our ignorance of the climate system is enormous. And I think you all need to understand that.

Senator INHOFE. Thank you very much.

Mr. CHRISTY. We cannot predict much at all.

Senator INHOFE. Thank you, Madam Chair.

Senator BOXER. I just want you to know I do remember when you did that, and you invited Al Gore to come and live in that house.

Senator INHOFE. It actually slept four people.

Senator BOXER. I remember it very clearly because the headline the next day, ABC News, was Inhofe Uses Blizzard to Refute Global Warming.

[Laughter.]

Senator BOXER. February 11, 2010. But that was a headline. And I think it is important for us to realize that it is absolutely true, it is not the weather; it is the climate.

Senator INHOFE. I do not think anyone at this table is going to have a problem with a headline that some biased reporter might use.

Senator SANDERS. Madam Chairman.

Senator BOXER. Just a moment. OK? Just relax, Senator.

Senator SANDERS. I am relaxed.

Senator BOXER. Well, you are not. You keep telling me this one, that one. We will continue this in a civil way, and we will not descend into saying one thing and then have the facts disprove it, because you have to make a point if the facts disprove what you say.

Senator SANDERS. Thank you.

I wanted to, because I believe that my good friend, and he is a good friend, and he is honest and he is sincere, Jim Inhofe, is in a sense the ideological leader of the Republicans on this issue, I am going to do my best to quote Senator Inhofe on his views of this issue. And Jim, if I am misquoting you, I want you to tell me. I am going to do my best to get you as accurate as I can, and I want the members of the panel to tell me whether Senator Inhofe is right or whether or not the scientific community disagrees with him.

Now, Senator Inhofe has said repeatedly, recently just the other day on the floor of the Senate and in his book, which I am reading, I am reading it, he gave it to me very kindly, and I am going to read every word of it, he said that in his view global warming is the greatest hoax ever perpetrated on the American people.

Now, my understanding is that NOAA says that global average surface temperatures have increased 1.3 degrees Fahrenheit since 1900. NASA says the global average surface temperatures of this planet have increased by 1.5 degrees Fahrenheit since 1880. Dr. Richard Muller recently wrote an article in which he said that the planet has warmed 2.5 degrees Fahrenheit over the last 250 years.

So either NASA, NOAA and many other scientists are correct in stating that the planet is warming, or perhaps Senator Inhofe is correct that global warming is a hoax.

Senator INHOFE. Just for a moment here. Stop the clock because I do not want to use——

Senator BOXER. Whoa, whoa, whoa, whoa.

Senator INHOFE. Well, he asked me the question, Madam Chairman.

Senator BOXER. Would you like the Senator to yield for a question?

Senator INHOFE. Yes.

Senator SANDERS. I would ask unanimous consent, I am going to yield. But I ask that it not be taken out of my time.

Senator BOXER. Absolutely.

Senator INHOFE. The original statement was that the notion that anthropogenic gases are causing catastrophic global warming is the greatest hoax ever perpetrated on the American people.

Senator SANDERS. OK.

Senator INHOFE. So, it was, that is a little addition to the definition.

Senator SANDERS. OK, thank you.

OK, so here is my question, very briefly because we do not have a lot of time, to the three scientists in front of us. Is the scientific community correct in believing that global warming is real? Or is Senator Inhofe correct in believing that global warming is a hoax?

Dr. Field.

Mr. FIELD. The scientific community is as close to unified as it is on anything ever in that global warming is unequivocal.

Senator SANDERS. Dr. Christy, is global warming real or is it a hoax?

Mr. CHRISTY. In the political context in which that was stated, I think I understand that it is overstated as a political issue.

Senator SANDERS. Is global warming real or is it a hoax?

Mr. CHRISTY. The world has warmed in the past 120 years.

Senator SANDERS. Pardon me?

Mr. CHRISTY. The world has warmed in the past 120 years.

Senator SANDERS. It has warmed in the last 120 years?

Mr. CHRISTY. Yes.

Senator SANDERS. So, those of us who believe in global warming, are we perpetrating a hoax?

Mr. CHRISTY. I think the question is how much is due to human effects, and can you do anything about it. That is the question.

Senator SANDERS. OK.

Dr. McCarthy, is global warming a hoax?

Mr. MCCARTHY. It is unequivocal the earth is warming, and I think the evidence that humans are contributing to it is also unequivocal.

Senator SANDERS. OK, next question. And again, I do not want to misquote my good friend. I would never do that. Senator Inhofe, he is very sincere about this. But we cannot have a debate unless we are being honest with each other.

Senator Inhofe said to NBC News in an interview in July 2010, "We are in a cycle now that all the scientists agree is going into a cooling period." Then, on the Senate floor on July 11th, Senator Inhofe said, "We went into a warming period that went up to the turn of the century. Now it is actually going down into a cooling period again."

I believe Senator Inhofe just referred a few moments ago to a recent period where we were going into an ice age. Question to the members of the panel. Senator Inhofe has suggested that we are in a cooling period since the year 2001. Others have testified that we are seeing a significant increase in temperature. Is Senator Inhofe right that we are in a cooling period over the last 10 or 11 years?

Dr. Field.

Mr. FIELD. There is no indication of any change in the rate of warming of the earth system over the last 10 years.

Senator SANDERS. Are we getting warmer, or are we going into a cooling period?

Mr. FIELD. Dr. McCarthy shared the conclusive evidence about the increased heat that is being accumulated in the oceans.

Senator SANDERS. OK.

Dr. Christy.

Mr. CHRISTY. It depends on what year you start and what year you end, but basically——

Senator SANDERS. Since 2001.

Mr. CHRISTY. That has been pretty flat in terms of temperature.

Senator SANDERS. You do not—OK.

Dr. McCarthy.

Mr. MCCARTHY. This last decade is the warmest on record. And if you look at the ocean cycles, particularly El Niño, you can understand that indeed this decade is also warming at about the same rate as earlier decades.

Senator SANDERS. Dr. Christy, you disagree with Dr. McCarthy?

Mr. CHRISTY. Oh, yes. In fact, I showed it in the chart.

Senator SANDERS. OK, thank you.

All right, next question. Getting back to the point that Senator Inhofe just made——

Senator INHOFE. Could I just interrupt and ask you a question at this point?

Senator SANDERS. Could you let me—I would appreciate it if you would let me ask my questions, then I would be happy to take any questions——

Senator BOXER. Well, if I could just say, we still have colleagues that have questions. We are not going to have any more interruptions.

Senator SANDERS. OK. Senator Inhofe says global warming is the greatest hoax ever perpetrated on the American people, and he had some ideas about who the perpetrators are. In an interview with this book, about his recent book, which was done with Craig Bannister, this is what he says.

Mr. Bannister says, now why do you call the global warming hoax a conspiracy? Senator Inhofe says, well, it is a hoax and a conspiracy, Craig, because they try to make it appear that we are all going to die if we do not line up and do what they want, what they tell us to do, in terms of anthropogenic gases, when in fact you have a bunch of people, you have the Al Gores, the George Soros, the MoveOn.org, the whole Hollywood elite group and all of them trying to run everyone else's lives.

And this is what their motivation is. To make people, for the kids, for example, make little kids and school kids believe that the world is coming to an end, and it is all man's fault, and it is all the fault primarily of the wealthier nations, and this is part of the hoax.

Question: Do you believe that global warming is a hoax being pushed by the United Nations, Al Gore, George Soros, the whole Hollywood elite and MoveOn.org?

Dr. Field.

Mr. FIELD. Global warming is certainly not a hoax.

Senator SANDERS. Dr. Christy.

Mr. CHRISTY. That question, I do not know how to answer. I would just say the global warming issue is highly overblown from what you look at real, hard core——

Senator SANDERS. Do you think the U.N. is engaging, and the Hollywood elite and Al Gore and all of these guys are pushing——

Mr. CHRISTY. I am not going to go to the motives of these people.

Senator SANDERS. OK. Fine.

Dr. McCarthy.

Mr. MCCARTHY. There is no hoax. There is no conspiracy.

Senator BOOZMAN. Madam Chair, point of order.

Senator BOXER. Thank you, Senator.

Senator BOOZMAN. Madam Chair.

Senator BOXER. Yes.

Senator BOOZMAN. I was under the impression that if a member in questioning mentions another member's name that he does have the right to respond. Is that correct or not?

Senator BOXER. Well, we do not have any such stated rules. But as you know, I did allow a couple of interruptions here. And if Senator Inhofe wants to take another round, we can all have another round.

Senator BOOZMAN. But I do think that is fair, I mean, in the sense that——

Senator BOXER. I will call on Senator Inhofe, but I would like to say we do not have any rules. We try to do this in a collegial way.

Senator Inhofe, I will give you 2 minutes.

Senator INHOFE. I do not need 2 minutes. I would only say this. The key to the question which was corrected by Senator Sanders is that anthropogenic gases is causing this. I would hope that when you get to the chapter on the United Nations that you read it very carefully, and then you and I can visit about that.

I ask unanimous consent that we include in the record at this point a statement that is by someone on your side of this issue, Jim Lovelock, who made the statement that the world has not warmed up very much in the millennium, 12 years is a reasonable time. And he goes on to say yes, it has leveled off now. So, there are other scientific opinions which are expressed in this document.

[The referenced information was not received at time of print.]

Senator BOXER. Thank you. Thank you very much. We are going to try to get through this a little bit faster here if we can. So we are going to turn now to Senator Sessions.

Senator SESSIONS. Let us go over this chart because we have a desperate, an aggressive, let me say, attempt to take weather difficulties and extreme events to paint a picture of climate change occurring in an unprecedented degree.

Dr. Christy, if we are having extreme weather events, it would seem to me that record lows and record highs would indicate that. Is that correct? One of the implications?

Mr. CHRISTY. Yes. If someone claims that, it is a claim that can be tested. I have heard the claim.

Senator SESSIONS. Now, this chart that indicates clearly, if you can see it, the blue represents record low temperatures; the red represents record high temperatures since the 1890s. And you have

taken—you have looked at stations that have been in existence for at least 80 years. Is that correct?

Mr. CHRISTY. Yes.

Senator SESSIONS. Is it not true that if you take a station that has been in existence for 25 years you could have a high but it would be only within that, at that station, over a 25-year period?

Mr. CHRISTY. That was the fallacy of all of these reports this year, that they used stations with only 30, 35, 40 years of data that did not include the 1930s and 1920s. And so you had all of these record highs.

Senator SESSIONS. So, in the 1930s, we did not have nearly as much CO_2 in the atmosphere as we have today?

Mr. CHRISTY. That is right.

Senator SESSIONS. Would you just explain to me, this is rather dramatic, since 1960 through today according to your data which takes NOAA's temperature records State by State, every single decade, this is not 1 year but every decade, there have been more cold lows than there have been warm highs. Is that correct?

Mr. CHRISTY. That is not consistent with what someone would want if warming were to occur. But as I say, and we talked earlier, extremes are pretty poor metric to use to claim something about climate change.

Senator SESSIONS. I would just want to say that that is a cause of concern as we as policymakers are asked to invest trillions of dollars of taxpayers' money. We need to consider whether or not this event is actually occurring and whether we just have more TV and weather channels that give more attention to these storms. We see the forest fires on the television. It does not mean we did not have forest fires previously. A forest fire is no proof of global warming. Give me a break.

But this is more troubling. Senator Inhofe has been attacked here. He said years ago—as a lone voice, frankly, I remember him speaking out—that he had doubts about these projections. And you expressed doubts about these projections—climate computer models—in your testimony before the Committee when I was on it years ago.

Would you explain what is happening in that chart and why that is an important chart?

Mr. CHRISTY. OK, this is about as simple as you can get. The black line is the average of the 34 latest IPCC climate models. The blue and red lines are two independent satellite temperature data sets. So, we are comparing apples to apples by starting in the same period and going forward in time. And you see that the temperatures have leveled off in the past 12 or 13 years when you look at this average, significantly different from what models say.

Senator SESSIONS. So the policy we have been asked to set over the last 15 years in the Congress have been based on the computer models, I would say. I mean, we have been told by the IPCC and other climate experts that these computers were predicting a dramatic increase in temperature. I would just say that the dramatic increase in temperature has not occurred, it seems to me, and I believe it calls on us all to be a bit cautious.

Can CO_2 increase temperature? I would think there is some logic to that theory. It could be a blanketing greenhouse gas. But how

much can we hammer working Americans with extreme electric bills and other costs for gasoline to try to confront the issue? This is a question that all of us have to wrestle with. And I believe Dr. Christy's testimony is accurate. I believe Senator Inhofe, whose skepticism has been courageously stated for a long time, has been proven more accurate than a lot of the scientists who have produced these models to date.

Thank you.

Senator BOXER. I will call on Senator Cardin.

He is not here, so I will call on Senator Lautenberg.

Senator LAUTENBERG. Thanks, Madam Chairman.

We are getting a semantic debate going here, as well as a review of science. And I wonder, there is quite a difference between a projection and a hoax. Projection is done in honest form by reading from whatever instruments or data one receives. But a hoax is a produced action to deceive people. None of you teach English but I know that you speak it very well.

And so what happened around here is there has been an attempt to discredit science, and it goes on continually to try and make a case for disbelieving what is in front of you.

Dr. McCarthy, in 2009 a hacker stole a number of e-mails from the climate change scientists. Conservatives, Republican news media have seized upon these e-mails to attack efforts to address climate change. Are you aware that anything was uncovered in those e-mails that undermined the scientific consensus on climate change?

Mr. MCCARTHY. Thank you, Senator. Indeed, there was a lot of press as you described, and it prompted a number of investigations. There were investigations conducted by Parliament in the U.K. since that is where the server was based, and that is where the theft presumably occurred.

There were investigations conducted by our National Science Foundation in this country because the National Science Foundation supported much of this work, through investigations conducted by all the universities in which the scientists who were involved in these exchanges of e-mail resigned. And none of those investigations found that there was any reason to question the science that was in play and discussed in these various matters.

There were questions about access to the data, the scientists were being harassed by people wanting their data, wanting their code, and there were questions about some really lousy papers that had been published and through the peer review process would not have to be dealt with in a very, very protracted way. But the science stands unaffected by any of the investigations. No fault was found. The scientists were guilty of bad manners.

Senator LAUTENBERG. Thank you.

Dr. Christy, your research on satellite temperature has often been used to challenge the reliability of climate change models. However, your research was shown to be wrong. Specifically, you failed to make the right adjustments for satellite orbit and other factors when analyzing the temperature data.

Once those errors were corrected, the satellite data confirmed the warming trend. Did your personal views regarding climate change affect your views of the research?

Mr. CHRISTY. No. First of all, I disagree with his view of Climategate, but we will go on to your question. Science is the process of getting to the best answer through time. Our data set changed by less than the error margin we had published already. And so even today our data set has a more warming trend than one of the other satellite data sets. So, that did not change because the errors were relatively small.

Senator LAUTENBERG. Relatively small. Well, they seemed to raise quite a degree of doubt in the scientific community that your analysis that the changes were relatively small; I do not think it is the popular view. So, you are entitled to your own bias, if you will.

Dr. McCarthy, you do a lot with the ocean, obviously, and its ability to encapsulate the information of change that we are seeing. What has happened up in the Arctic and the Antarctic? And has there been any effect of climate change in these regions?

Mr. MCCARTHY. The Arctic has changed profoundly. I show graphs in my written testimony of the loss of sea ice in the Arctic. The data is only really precise since 1980, but we are setting new records already in June and July of this year for a low sea ice extent in the Arctic.

Also, you would expect this warming to affect ice on Greenland, and it certainly is, not only by warming the atmosphere but also warming of the ocean. The Petermann Glacier slide that Senator Boxer showed, this is a tidewater glacier. The glacial tongue sticks out into the ocean. And these are the glaciers that are retreating most rapidly because the ocean is warming.

So, yes, Greenland and Antarctica are both losing ice. The warming ocean is eating away at the tidewater glaciers so they are retreating very quickly, and sea ice is being lost in the central Arctic because of a warmer atmosphere.

Senator LAUTENBERG. In a trip that I made with some of my colleagues here to Greenland, and ultimately I went down to the South Pole, and species mammals had radical changes in their population over this period of time. And they are ocean dependent. Are those real changes or are we imagining these?

Mr. MCCARTHY. The first slide I showed had 10 physical indicators. We could have a whole other chart that showed biological indicators. On every planet right now, every planet, excuse me, every continent on this planet, we have one planet, unfortunately, only one, every continent on this planet you are seeing changes in the distribution of organisms which are indicative of a change in climate. And the direction they are changing, whether it is their range or their time of migration or flowering, are consistent with the local changes which in many cases are warmer, wetter, or drier. And we are seeing similar trends in the ocean.

Senator LAUTENBERG. Madam Chairman, I did not mean to run over, but I thought since the disputation that was going on here took some time that I would have some license to do it.

Senator BOXER. You have your license, Senator.

Senator LAUTENBERG. One license more, and that is, how come the things we are seeing are not really there? This is the mystery that we are facing here.

Thank you very much.

Senator BOXER. Yes. That is interesting.

[Laugher.]

Senator BOXER. Senator Boozman, you have the last questions.

Senator BOOZMAN. Thank you, Madam Chair.

Again, Senator Lautenberg suggested that what we are seeing is not really there. As scientists, you do not really think in those terms, do you? In the sense of trying to correlate what is going on this summer with a pattern? Is that correct?

Senator BOXER. Who are you asking it to?

Senator BOOZMAN. Just whoever wants to jump in.

Mr. FIELD. The scientific method is a spectacularly powerful tool for extracting inference, and on top of that the process of doing these assessments is a wonderful way to sort through all of the published literature. What we do is make observations, interpret, sort through, and present through the peer view process.

Senator BOOZMAN. I guess my point is that is a lot hotter in Arkansas this summer than it was last summer. Many centuries ago it was a lot colder, during the ice age, whatever caused that, than it is now. I guess what I am saying is that it is dangerous to really infer, and you can correct me from just what is going on this summer as compared to the whole deal.

One thing that bothers me a little bit is that there is really a tendency, I am hearing, and we are not going to be able to decide whether exactly what is going on today or who is causing it or this or that, but I am bothered when I hear scientists say it is this way or that way. OK? In the sense that we can recount throughout history, and throughout recent history, all kinds of times when the scientific community was completely in agreement that this or that was that way and it was not that way. So, I do think as scientists we really do need to continually, the statements, it is this way or that way, are not really helpful.

When I was in high school I was told that we would be out of our natural gas in 20 years. We have got more natural gas now than ever. OK? Y2K. I am sure that all of you adjusted your computers, and the scientific community agreed completely that if we did not adjust our computers at the time it was true that we going to have all of this stuff gone. But the reality is no computer any place caused any problem.

So I do think that as we discuss these things, it is dangerous, it is this way, period. And I am really hearing some of that from some of you all.

My question is, the dilemma that we have is if this is manmade, how do we respond to that? In Arkansas, electricity would rise by, if we went to cap and trade, which was suggested by some here, electricity would rise $1,358 a year and $1.27 per gallon increase in gasoline prices. The question is, what does that do to our single moms? What does it do to our people on fixed incomes? What does it do to our economy?

And so what we are grasping with, and you all can be helpful, even if it were true, that we are in a global warming situation because of CO_2, what could possibly be done that would counter that in a sense especially with China, India, places like that not going along with it, which they have said they will not.

Yes, sir.

Mr. CHRISTY. I would just say on the other side of that is, would that have any effect on the climate anyway?

Senator BOOZMAN. Yes, that is my point.

Mr. CHRISTY. The answer is no, that is so minuscule as to be so undetectable and unpredictable and unattributable.

Senator BOOZMAN. And have you two, go ahead, sir, have you done any research that says if we do this or that that this or that is going to happen, and it is worth the $1,300 a year and $1.27 in gasoline——

Senator SANDERS. Would the gentleman yield? And contribute time to him. Just for one question. Where do you get that, where do those numbers come from? Those are not numbers that I am familiar with nor do I agree with.

Senator BOOZMAN. It is a study from David Kreutzer, Ph.D., Senior Policy Analyst in Energy, Economics and Climate Change, and Karen Campbell, Ph.D., William W. Beach, Director of the Center for Data Analysis Energy and Environment and Nicolas Loris.

Senator SANDERS. You have one study then, Senator, that says that other studies would disagree?

Senator BOOZMAN. But I have no reason to, I think everyone during the discussion of cap and trade, energy trade would go up significantly and that was the mechanism of controlling the use of energy.

Senator INHOFE. And that is what the President said.

[The referenced information follows:]

WebMemo

Published by The Heritage Foundation

No. 2580
August 6, 2009

Heritage Analysis of Waxman–Markey Hits Where Others Miss

David W. Kreutzer, Ph.D.

On June 26, the House of Representatives narrowly passed climate change legislation designed by Henry Waxman (D–CA) and Edward Markey (D–MA). The 1,427-page bill would restrict greenhouse gas emissions from industry, mainly carbon dioxide from the combustion of coal, oil, and natural gas.

If passed by the Senate, the bill would burden families with thousands of dollars per year in direct and indirect energy costs. Additional thousands of dollars of income would be lost, and the national debt would jump by tens of thousands of dollars per family. Job losses due to Waxman–Markey's energy restrictions would be in the millions.

How Cap and Trade Works. Waxman–Markey is an energy tax of historic proportions. Called "cap and trade" by its supporters, the bill would limit man-made greenhouse gas emissions by instituting a declining cap on allowable emissions. Electricity producers, petroleum refiners, and natural gas distributors would have to obtain permits, called "allowances," from the federal government for every ton of CO_2 emissions they produce.

Since the government issues fewer allowances in each subsequent year, the allowance price has to rise to meet demand. That is, the cost of an allowance is a tax, and the tax rises each year. As with any tax, it will ultimately be passed on to consumers in the form of higher energy and product prices. The total value of the allowances (the tax revenue) would be hundreds of billions of dollars per year and will have an aggregate value of $5.7 trillion by 2035. This makes Waxman–Markey one of the largest new taxes in history, if not the largest.

In particular, the Heritage analysis projects that by 2035 the economic impacts (in constant 2009 dollars) of this bill are:[1]

- Gasoline prices will rise 58 percent (or $1.38);
- Natural gas prices will rise 55 percent;
- Heating oil prices will rise 56 percent;
- Electricity prices will rise 90 percent;
- A family of four can expect its per-year energy costs to rise by $1,241;
- Including taxes, a family of four will pay an additional $4,609 per year;
- A family of four will reduce its consumption of goods and services by up to $3,000 per year, as its income and savings fall;
- Aggregate GDP losses will be $9.4 trillion;
- Aggregate cap-and-trade energy taxes will be $5.7 trillion;
- Job losses will be nearly 2.5 million; and
- The national debt will rise an additional $12,803 per person ($51,212 per family of four).

This paper, in its entirety, can be found at:
www.heritage.org/Research/EnergyandEnvironment/wm2580.cfm
Produced by the Center for Data Analysis
Published by The Heritage Foundation
214 Massachusetts Avenue, NE
Washington, DC 20002–4999
(202) 546-4400 • heritage.org

The Heritage Foundation
LEADERSHIP FOR AMERICA

(All of these price and cost increases are above and beyond those expected to occur without the legislation.)

As President Obama said about his cap-and-trade program during the presidential election campaign, "electricity prices would necessarily skyrocket."[2] The same applies to many other products as the Waxman–Markey energy tax spreads through the economy as businesses and consumers adapt to higher energy prices.

People would spend more for less energy; build smaller houses and buildings; drive smaller, less safe vehicles; turn their thermostats up in the summer and down in the winter; and divert income to more expensive energy-saving appliances. But savings from these activities and more would not be enough to offset the higher energy costs. The net effect is lower income, higher prices, and fewer jobs.

What Makes the Heritage Study Different. An oft-cited study from the Congressional Budget Office (CBO) claims that the cost of Waxman–Markey would be less than $200 per year per family, or "a postage stamp per day." However, the CBO report does not even attempt to measure the impact on national income—an impact estimated to be in the thousands.

Another frequently cited study comes from the Environmental Protection Agency (EPA).[3] The EPA makes some very questionable assumptions about how CO_2 caps would be met, especially concerning the growth of nuclear power and the ability to forego industrial CO_2 cuts by paying farmers to grow trees and foreigners to cut their CO_2 emissions (known as offsets). The magnitude of offsets in the EPA's latest report is much larger than in their preliminary analysis of Waxman–Markey.

But the factor least understood is the EPA's use of discounting, a financial tool for comparing costs and benefits that occur at different times. Discounting is a legitimate tool for cost-benefit analysis, but it can give a distorted picture of the magnitude of costs for the period in which they occur.

For instance, the EPA projects that the real cost (adjusted for inflation) to a household of 2.6 people will be $1,287 lost consumption in 2050. However, after discounting, this figure is reduced to $140. Here, discounting tells us that $140 invested at a riskless 5 percent per year will be worth $1,287 in 41 years. It in no way says that 41 years from now the lost consumption will be $140.

Since consumption comes after taxes and savings, the $1,287 is much less than the lost income in the first place. So the EPA cost, with all of its questionable assumptions, is over $2,700 in 2050 when converted to lost income for a family of four—even after adjusting for inflation.

In short, the EPA and the CBO studies are not comprehensive measures of the economic impact of Waxman–Markey in simple, inflation-adjusted dollars.

In contrast, analyses by The Heritage Foundation and the Brookings Institution—two organizations often portrayed as ideological opposites—study the overall impact of Waxman–Markey on the economy, including the effects of higher production costs and lower economic output. These studies show that Waxman–Markey would lead to significant economic losses—on the order of thousands of dollars

1. See David W. Kreutzer, Karen A. Campbell, William W. Beach, Ben Lieberman, and Nicolas D. Loris, "The Economic Consequences of Waxman-Markey: An Analysis of the American Clean Energy and Security Act of 2009," Heritage Foundation *Center for Data Analysis Report* No. 09-04, August 6, 2009, at *http://www.heritage.org/Research/EnergyandEnvironment/cda09-04.cfm*. For analysis of other cap-and-trade legislation, see William W. Beach, David W. Kreutzer, Ben Lieberman, and Nicolas D. Loris, "The Economic Costs of the Lieberman-Warner Climate Change Legislation," Heritage Foundation *Center for Data Analysis Report* No. 08-02, May 12, 2008, at *http://www.heritage.org/Research/EnergyandEnvironment/cda08-02.cfm*.
2. As quoted in Paul Chesser, "Obama's Plan 'Necessarily' Skyrockets Energy Bills," *Washington Examiner*, May 1, 2009, at *http://www.washingtonexaminer.com/opinion/columns/OpEd-Contributor/Obamas-plan-necessarily-skyrockets-energy-bills-44124402.html* (August 5, 2009).
3. Environmental Protection Agency, "EPA Analysis of the American Clean Energy and Security Act of 2009 H.R. 2454 in the 111th Congress," June 23, 2009, at *http://www.epa.gov/climatechange/economics/pdfs/HR2454_Analysis.pdf* (July 25, 2009).

No. 2580 WebMemo August 6, 2009

per family per year. Analysis done by CRA International for the National Black Chamber of Commerce comes to a similar conclusion.[4]

Taxing and Spending. The Heritage Foundation analysis exposes Waxman–Markey as a new tax of a historic magnitude. As could be expected, such a large revenue stream has attracted an army of lobbyists seeking a share. (The Center for Public Integrity estimates that over 2,300 lobbyists are involved.[5])

Congress has obliged—and then some. For the first 15 years (2012–2026) of the Waxman–Markey regime, over 88 percent of the revenue is given to various special interest groups. In fact, more than 100 percent has been promised for the years 2016 and 2017.[6] So this historic tax increase has been matched by a historic spending spree.

Another Burden on Future Generations. The income losses, the job losses, the tax increases, and the mounting debt all get worse over the coming decades. The Waxman–Markey bill forces a bad deal on a generation that does not have the option to turn it down.

The $9.4 trillion of lost income, the 2.5 million lost jobs, the $5.0 trillion of additional national debt, and the $5.7 trillion in new taxes will buy no more than a 0.2 degree (Celsius) moderation in world temperature increases by 2100 and no more than a 0.05 degree reduction by 2050.

—David W. Kreutzer, Ph.D., is Senior Policy Analyst for Energy Economics and Climate Change in the Center for Data Analysis at The Heritage Foundation.

4. Congressional Budget Office, "The Estimated Costs to Households from the Cap-and-Trade Provisions of H.R. 2454," June 19, 2009, at *http://www.cbo.gov/ftpdocs/103xx/doc10327/06-19-CapAndTradeCosts.pdf* (July 25, 2009); David Montgomery et al., "Impact on the Economy of the American Clean Energy and Security Act of 2009 (H.R.2454)," CRA International, May 2009, at *http://www.nationalbcc.org/images/stories/documents/CRA_Waxman-Markey_%205-20-09_v8.pdf* (July 25, 2009); Warwick McKibbin, Pete Wilcoxen, and Adele Morris, "Consequences of Cap and Trade," Brookings Institution, June 8, 2009, at *http://www.brookings.edu/~/media/Files/events/2009/0608_climate_change_economy/20090608_climate_change_economy.pdf* (July 25, 2009).
5. Center for Public Integrity, "Latest Center Analysis Reveals Explosive Growth in the Climate Change Lobby," February 25, 2009, at *http://www.publicintegrity.org/news/entry/1187/* (August 5, 2009).
6. Tim Carr, "Waxman-Markey Just Doesn't Add Up," The Foundry, August 4, 2009, at *http://blog.heritage.org/2009/08/04/waxman-markey-just-doesnt-add-up/*.

WebMemo

Published by The Heritage Foundation

No. 2585-AR
August 19, 2009

Impact of the Waxman–Markey Climate Change Legislation on Arkansas

David W. Kreutzer, Ph.D., Karen A. Campbell, Ph.D., William W. Beach, Ben Lieberman, and Nicolas D. Loris

On June 26, a 1,427-page climate change bill introduced by Representatives Henry Waxman (D–CA) and Edward Markey (D–MA) passed the House by a narrow margin. The bill, also known as Waxman–Markey, includes a number of alarming provisions, chief among them a cap-and-trade program that would attempt to curb global warming by imposing strict upper limits on the emission of six greenhouse gases, with the primary emphasis on carbon dioxide (CO_2). The mechanism for capping these emissions requires emitters to acquire federally created permits (or "allowances") for each ton of greenhouse gas emitted.

Because these allowances carry a price—and because 85 percent of the United States' energy needs come from carbon-emitting fossil fuels—Waxman–Markey is best described as a significant tax on energy use. Since everything Americans use and produce requires energy, the tax hits U.S. pocketbooks again and again. The Heritage Foundation's Center for Data Analysis forecasts severe consequences, including skyrocketing energy costs, millions of jobs lost, and falling household income and economic activity—all for negligible changes in the global temperature.[1]

Workers and families in Arkansas may be wondering how cap-and-trade legislation would affect their income, their jobs, and the cost of energy. Implementing Waxman–Markey would put a chokehold on Arkansas's economic potential, reducing gross state product by $3.67 billion in 2035.

The Waxman–Markey Effect

For the state of Arkansas, over the 2012–2035 timeframe, on average the Waxman–Markey bill would:

- Lower gross state product by **$2,182 million,**
- Reduce personal income by **$868 million,**
- Destroy **10,807 jobs,**
- Raise electricity prices by **$700.85 per household,**
- Raise gasoline prices by **$0.61 per gallon.**

Source: Heritage Foundation calculations based on the IHS/Global Insight U.S. Macroeconomic and Energy models.

Table 1 • WM 2585-AR heritage.org

Consumers would be hit hard. Between 2012 (when the restrictions first apply) and 2035 (the last year of this analysis), the prices of electricity and gasoline will rise sharply when compared to prices in a world without cap and trade. By 2035, Americans living in the state of Arkansas will see their electricity prices rise by $1,358.72 and their gasoline prices rise by $1.27 per gallon solely because of Waxman–Markey.

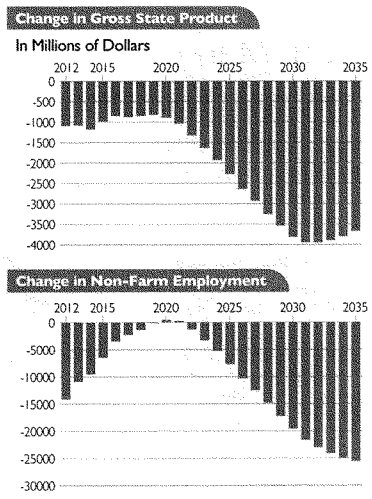
This paper, in its entirety, can be found at:
www.heritage.org/Research/EnergyandEnvironment/wm2585-AR.cfm
Produced by the Center for Data Analysis
Published by The Heritage Foundation
214 Massachusetts Avenue, NE
Washington, DC 20002–4999
(202) 546-4400 • heritage.org

The Heritage Foundation
LEADERSHIP FOR AMERICA

No. 2585-AR WebMemo August 19, 2009

Economic Indicators in Arkansas

Changes in Arkansas's economy due to the Waxman–Markey climate change bill. Figures are adjusted for inflation.

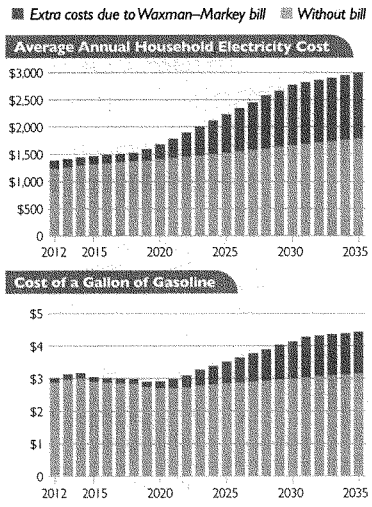


Source: Heritage Foundation calculations using the IHS/Global Insight U.S. Macroeconomic model.

Chart 1 • WM 2585-AR heritage.org

Utility Costs in Arkansas

Costs for electricity and gasoline in Arkansas with and without the Waxman–Markey climate change bill. Figures are adjusted for inflation.



Source: Heritage Foundation calculations using the IHS/Global Insight U.S. Macroeconomic model.

Chart 2 • WM 2585-AR heritage.org

As the economy adjusts to shrinking gross domestic product (GDP) and rising energy prices, employment will take a big hit in Arkansas. Beginning in 2012, job losses will be 14,133 higher than without a cap-and-trade bill in place. And the number of jobs lost will only go up, increasing to 25,594 by 2035.

Contrary to the claims of an economic boost from green investment and green job creation and "postage stamp" costs, the Waxman–Markey climate change legislation does the complete opposite by increasing energy prices—thereby causing a considerable reduction in the rate of economic growth, the amount of GDP, household incomes, and employment.

—David W. Kreutzer, Ph.D., is Senior Policy Analyst for Energy Economics and Climate Change, Karen A. Campbell, Ph.D., is Policy Analyst in Macroeconomics, William W. Beach is Director of the Center for Data Analysis, Ben Lieberman is Senior Policy Analyst in Energy and the Environment, and Nicolas D. Loris is a Research Assistant in the Thomas A. Roe Institute for Economic Policy Studies at The Heritage Foundation.

1. Chip Knappenberger, "Climate Impacts of Waxman–Markey (the IPCC-Based Arithmetic of No Gain)," MasterResource, May 6, 2009, at *http://masterresource.org/?p=2355* (August 3, 2009).

The Heritage Foundation LEADERSHIP FOR AMERICA

WebMemo

Published by The Heritage Foundation

No. 2705
November 19, 2009

Discounting and Climate Change Economics: Estimating the Cost of Cap and Trade

David W. Kreutzer, Ph.D.

The Environmental Protection Agency (EPA) recently released its preliminary analysis of the Boxer–Kerry cap-and-trade bill. It largely reheats their analysis of the Waxman–Markey bill from last summer.

Proponents of both bills often claim the EPA analyses pegs the cost per household at a postage stamp per day. However, the reality is that the costs of both bills are far from trivial.

The Real Cost of a Car. The EPA lists the cost of the Waxman–Markey energy tax for the year 2050 at just $174 per household. Summed over all households, this figure still adds up to tens of billions of dollars per year, but it is relatively small in a world of trillion-dollar proposals. The problem is that that amount is not what the actual cost would be.

If inflation over the next 40 years equals that of the past 40, the EPA analysis would project that Waxman–Markey would cut consumption by $7,465 per household per year in 2050. The impact for Boxer–Kerry would be similar.

How, then, does the EPA transform $7,465 into $174? It adjusts for inflation and then takes the discounted present value. It is this second step that can be misleading.

To help sort this out, imagine that a time machine takes analysts back to 1969—a time when the average price of a new car was about $3,500. Once back in 1969, the exercise is to explain to Congress how much a new car will cost 40 years later in 2009.

Having already lived to see 2009, we know the average price for a new car is about $23,000. But telling the Congress of 1969 that in 40 years cars will cost $23,000 would give an exaggerated notion of the cost increase, because inflation alone will have increased prices by a factor of 5.8. If inflation is taken into account, the price of a new car in 2009 is about $4,000 in 1969 dollars.

From 1969 to 2009, car prices increased, but so did bread prices, housing prices, clothes prices, wages, income, and nearly everything else. Since money is the measuring stick for cost, this measuring stick changes with inflation.

When people buy cars, the real cost is defined as what they have to give up in order to afford the car: clothes, food, dinners out, etc. Economists adjust prices for different years to eliminate the impact of inflation so that a price increase means a good's price has risen relative to that of other goods.

A Steep Discount. In any event, it is not adjusting for inflation that turns the EPA's $7,465 cost for 2050 into $174. Adjusting for inflation brings the annual cost down quite a bit, but the hit is still $1,287 per household, well above a postage stamp per day.

What, then, does the EPA do to turn $1,287 into $174? They take the discounted present value using a real discount (interest) rate of 5 percent.

This paper, in its entirety, can be found at:
www.heritage.org/Research/EnergyandEnvironment/wm2705.cfm

Produced by the Center for Data Analysis

Published by The Heritage Foundation
214 Massachusetts Avenue, NE
Washington, DC 20002–4999
(202) 546-4400 • heritage.org

The Heritage Foundation
LEADERSHIP FOR AMERICA

No. 2705 WebMemo November 19, 2009

Discounting is a legitimate tool in finance and for cost–benefit calculations. But discounting can give a much distorted view of costs, as is done by those misrepresenting the EPA analysis.

The car example may help illustrate this problem. Taking the inflation-adjusted (1969 dollars) $4,000 price of the average new car in 2009 and discounting it in the EPA fashion would generate a present value in 1969 of $562.[1] This is clearly much less than the cost of an average car in 2009, even after adjusting for inflation.

What then is this $562? It is the amount when invested for 40 years, at an interest rate guaranteed to be 5 percent above inflation, that would buy the $23,000 car. In other words, if a person in 1969 invested $562 at 9.72 percent interest (5 percent above inflation), letting all of the interest compound and paying no taxes, it would now amount to $23,000, enough to buy a new car.

With similar logic, if every household in 2010 invests $174 at 5 percent above inflation (guaranteed and with no taxes), then in 2050 (assuming inflation in the next four decades is the same as the last four), it would amount to $7,465, or enough to pay for one year's worth of the consumption that Waxman–Markey would have destroyed. Of course, most of the households of 2050 do not exist in 2009.

In any event, the discounted value is not the amount households will have to pay each year, even with discounting. In the most generous case, the present value is the amount that would have to be paid for one year, right now, if the present value for each of the 40 years were paid in one lump sum right now—that is, if the cost for all 40 years were paid at once. So no matter how it is sliced, there is no sense in which a postage stamp per day reflects the annual cost of the cap-and-trade legislation.

Just as the inflation-adjusted, undiscounted $4,000 average price of a 2009 car would best explain the future cost to people in 1969, the inflation-adjusted, undiscounted $1,287 would be the best measure of the EPA's projected per household consumption loss due to Waxman–Markey for the single year of 2050. But per-household consumption loss may not be the best measure of cost.

Adding to the Cost. When income drops, people prevent consumption from dropping by dipping into savings. In turn, lower savings reduces the ability of families to cope with other shocks and reduces their future income. Further, consumption comes from after-tax dollars, so losses in tax revenue do not show up in data on household consumption. The real economic cost is the loss of income.

Change in national income, as measured by gross domestic product (GDP), is a better measure of the overall economic impact of a policy. Since consumption expenditures are about 31 percent less than GDP, the lost income corresponding to the EPA's lost consumption calculation would actually be $1,867.

Lastly, a household is not necessarily a family. Three college students sharing an apartment are a household according to government statistics, but in reality they are part of three separate families. The EPA uses the average household size of 2.6 for its cost impact. Adjusting household size to a family-of-four standard adds another 53 percent, bringing the cost of cap and trade to $2,872 per family per year.

Very Expensive Postage. The EPA, with some very generous assumptions (doubling nuclear power output in 25 years, for example), projects that the Waxman–Markey energy tax will have an impact of $174 per household in 2050 in present discounted value. However, even using the EPA results shows that the inflation-adjusted impact per family of four would be much higher at $2,872 per year in 2050. Those are some very expensive postage stamps.

Again, though discounting is a useful tool for some financial calculations and when properly employed in cost-benefit analysis, it is not appropriate for giving an accurate picture of future prices. Saying cap and trade will cost a postage stamp per day is equivalent to saying the average new car today costs $562. It is clearly wrong.

—David W. Kreutzer, Ph.D., is Senior Policy Analyst for Energy Economics and Climate Change in the Center for Data Analysis at The Heritage Foundation.

1. Adjusting $23,000 to 1969 prices using the CPI calculator at the Federal Reserve Bank of Minneapolis's Web site (*http://www.minneapolisfed.org/index.cfm*) yields $3,959.19. Discounting that figure at 5 percent for 40 years gives $562.36.

The Heritage Foundation LEADERSHIP FOR AMERICA

Mr. FIELD. Senator, thank you for the question. And it is a great question. What is important to recognize is that what we are trying to do is provide sufficient information for policymakers to make good decisions, to try to figure out ways to avoid the damages that come from the climate change without providing unacceptable costs to the rest of society.

And we are really trying to find smart ways to move forward, recognizing what is happening, recognizing what the risks are, and that there are consequences of using the atmosphere as a dump for greenhouse gases, just the same way there are consequences of making changes in the economy that are intended to alleviate those damages.

The estimates from the IPCC indicate that the cost of stabilizing atmospheric CO_2 at something like 550 ppm could be anywhere from a net benefit to the economy to resulting in something like in 2050 that we would reach a level of wealth 1 year later than we would otherwise do it.

Senator BOXER. OK. Wow. Very intense conversation. And I want to thank colleagues.

I am going to ask unanimous consent to place in the record a chart based on NOAA temperatures that directly refutes Senator Sessions' chart. So then we will have two charts, one that shows that since 1950, well, since 1990, there have been more record highs than record lows, all the way to the present. So, we will put that in and we can look at both of those and see which one we agree with.

Senator SANDERS. Madam Chairman, a unanimous consent——

Senator BOXER. Yes, go ahead.

Senator SANDERS [continuing]. To place into the record, just in response to my friend Senator Boozman, a study done by McKinsey Consultants which says U.S. can meet entire 2020 emissions target with efficiency in cogeneration while lowering the nation's energy bill $700 billion.

[The referenced information was not received at time of print.]

Senator BOXER. OK. Well, I think what is important——

Senator SESSIONS. Madam Chairman.

Senator BOXER. Yes, sir.

Senator SESSIONS. I was just going to offer for the record——

Senator BOXER. Yes, please go ahead.

Senator SESSIONS [continuing]. The recent Wall Street Journal article by a number of respected scientists who say that we should not be panicking about global warming and point out many of the problems with the theory.

[The referenced information follows:]

The webpage cannot be found

HTTP

THE WALL STREET JOURNAL.
WSJ.com

OPINION

No Need to Panic About Global Warming

There's no compelling scientific argument for drastic action to 'decarbonize' the world's economy.

Editor's Note: The following has been signed by the 16 scientists listed at the end of the article:

A candidate for public office in any contemporary democracy may have to consider what, if anything, to do about "global warming." Candidates should understand that the oft-repeated claim that nearly all scientists demand that something dramatic be done to stop global warming is not true. In fact, a large and growing number of distinguished scientists and engineers do not agree that drastic actions on global warming are needed.

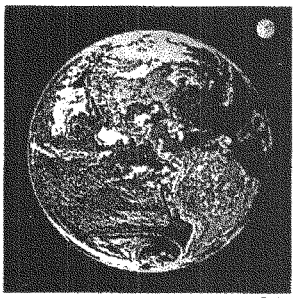
In September, Nobel Prize-winning physicist Ivar Giaever, a supporter of President Obama in the last election, publicly resigned from the American Physical Society (APS) with a letter that begins: "I did not renew [my membership] because I cannot live with the [APS policy] statement: 'The evidence is incontrovertible: Global warming is occurring. If no mitigating actions are taken, significant disruptions in the Earth's physical and ecological systems, social systems, security and human health are likely to occur. We must reduce emissions of greenhouse gases beginning now.' In the APS it is OK to discuss whether the mass of the proton changes over time and how a multi-universe behaves, but the evidence of global warming is incontrovertible?"

In spite of a multidecade international campaign to enforce the message that increasing amounts of the "pollutant" carbon dioxide will destroy civilization, large numbers of scientists, many very prominent, share the opinions of Dr. Giaever. And the number of scientific "heretics" is growing with each passing year. The reason is a collection of stubborn scientific facts.

Perhaps the most inconvenient fact is the lack of global warming for well over 10 years now. This is known to the warming establishment, as one can see from the 2009 "Climategate" email of climate scientist Kevin Trenberth: "The fact is that we can't account for the lack of warming at the moment and it is a travesty that we can't." But the warming is only missing if one believes computer models where so-called feedbacks involving water vapor and clouds greatly amplify the small effect of CO_2.

The lack of warming for more than a decade—indeed, the smaller-than-predicted warming over the 22 years since the U.N.'s Intergovernmental Panel on Climate Change (IPCC) began issuing projections—suggests that computer models have greatly exaggerated how much warming additional CO_2 can cause. Faced with this embarrassment, those promoting alarm have shifted their drumbeat from warming to weather extremes, to enable anything unusual that happens in our chaotic climate to be ascribed to CO_2.

The fact is that CO_2 is not a pollutant. CO_2 is a colorless and odorless gas, exhaled at high concentrations by each of us, and a key component of the biosphere's life cycle. Plants do so much better with more CO_2 that greenhouse operators often increase the CO_2 concentrations by factors of three or four to get better growth. This is no surprise since plants and animals evolved when CO_2 concentrations were about 10 times larger than they are today. Better plant varieties, chemical fertilizers and agricultural management contributed to the great increase in agricultural yields of the past century, but part of the increase almost certainly came from additional CO_2 in the atmosphere.



Corbis

Although the number of publicly dissenting scientists is growing, many young scientists furtively say that while they also have serious doubts about the global-warming message, they are afraid to speak up for fear of not being promoted—or worse. They have good reason to worry. In 2003, Dr. Chris de Freitas, the editor of the journal Climate Research, dared to publish a peer-reviewed article with the politically incorrect (but factually correct) conclusion that the recent warming is not unusual in the context of climate changes over the past thousand years. The international warming establishment quickly mounted a determined campaign to have Dr. de Freitas removed from his editorial job and fired from his university position. Fortunately, Dr. de Freitas was able to keep his university job.

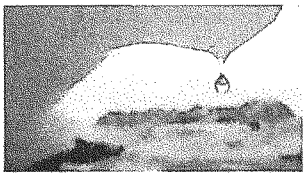
This is not the way science is supposed to work, but we have seen it before—for example, in the frightening period when Trofim Lysenko hijacked biology in the Soviet Union. Soviet biologists who revealed that they believed in genes, which Lysenko maintained were a bourgeois fiction, were fired from their jobs. Many were sent to the gulag and some were condemned to death.

Why is there so much passion about global warming, and why has the issue become so vexing that the American Physical Society, from which Dr. Giaever resigned a few months ago, refused the seemingly reasonable request by many of its members to remove the word "incontrovertible" from its description of a scientific issue? There are several reasons, but a good place to start is the old question "cui bono?" Or the modern update, "Follow the money."

Alarmism over climate is of great benefit to many, providing government funding for academic research and a reason for government bureaucracies to grow. Alarmism also offers an excuse for governments to raise taxes, taxpayer-funded subsidies for businesses that understand how to work the political system, and a lure for big donations to charitable foundations promising to save the planet. Lysenko and his team lived very well, and they fiercely defended their dogma and the privileges it brought them.

Speaking for many scientists and engineers who have looked carefully and independently at the science of climate, we have a message to any candidate for public office: There is no compelling scientific argument for drastic action to "decarbonize" the world's economy. Even if one accepts the inflated climate forecasts of the IPCC, aggressive greenhouse-gas control policies are not justified economically.

Related Video



Princeton physics professor William Happer on why a large number of scientists don't believe that carbon dioxide is causing global warming.

A recent study of a wide variety of policy options by Yale economist William Nordhaus showed that nearly the highest benefit-to-cost ratio is achieved for a policy that allows 50 more years of economic growth unimpeded by greenhouse gas controls. This would be especially beneficial to the less-developed parts of the world that would like to share some of the same advantages of material well-being, health and life expectancy that the fully developed parts of the world enjoy now. Many other policy responses would have a negative return on investment. And it is likely that more CO_2 and the modest warming that may come with it will be an overall benefit to the planet.

If elected officials feel compelled to "do something" about climate, we recommend supporting the excellent scientists who are increasing our understanding of climate with well-designed instruments on satellites, in the oceans and on land, and in the analysis of observational data. The better we understand climate, the better we can cope with its ever-changing nature, which has complicated

human life throughout history. However, much of the huge private and government investment in climate is badly in need of critical review.

Every candidate should support rational measures to protect and improve our environment, but it makes no sense at all to back expensive programs that divert resources from real needs and are based on alarming but untenable claims of "incontrovertible" evidence.

Claude Allegre, former director of the Institute for the Study of the Earth, University of Paris; J. Scott Armstrong, cofounder of the Journal of Forecasting and the International Journal of Forecasting; Jan Breslow, head of the Laboratory of Biochemical Genetics and Metabolism, Rockefeller University; Roger Cohen, fellow, American Physical Society; Edward David, member, National Academy of Engineering and National Academy of Sciences; William Happer, professor of physics, Princeton; Michael Kelly, professor of technology, University of Cambridge, U.K.; William Kininmonth, former head of climate research at the Australian Bureau of Meteorology; Richard Lindzen, professor of atmospheric sciences, MIT; James McGrath, professor of chemistry, Virginia Technical University; Rodney Nichols, former president and CEO of the New York Academy of Sciences; Burt Rutan, aerospace engineer, designer of Voyager and SpaceShipOne; Harrison H. Schmitt, Apollo 17 astronaut and former U.S. senator; Nir Shaviv, professor of astrophysics, Hebrew University, Jerusalem; Henk Tennekes, former director, Royal Dutch Meteorological Service; Antonio Zichichi, president of the World Federation of Scientists, Geneva.

Senator BOXER. OK. And I would just clarify for the record, I am not panicked about global warming. I just feel that Congress is the only place that seems to just shrug its shoulders, and even though admitting that it is occurring, does not really want to do much about it.

I will also place in the record several studies that confirm that, in essence, at the end of the day our consumers will save a lot of money once they have energy efficiency put into place and we have, we are energy independent, independent of the nations that do not like us very much. Once that happens, we will see a reduction in costs for the individual.

[The referenced information was not received at time of print.]

Senator BOXER. I want to thank all of you scientists for being here. We greatly appreciate this. And we will call you back because we are going to keep on this as long as it takes to get some action here in the U.S. Senate.

And Senator Inhofe has something for the record.

Senator INHOFE. For the record, I would like to have the report that shows, it came from a number of universities, that if we were to do the cap and trade as has been described in several pieces of legislation, the cost to the American people would be between $300 billion and $400 billion a year, which is 10 times greater than the tax increase of 1993.

Senator BOXER. OK. And I would put into the record a direct refutation of that.

So, we start off, unfortunately, where we left off, which is the Republican side denying and saying even if they agree, let us not doing anything about this——

Senator SESSIONS. Well, we could agree on something, Madam Chair——

Senator BOXER. Yes, go ahead, tell me.

Senator SESSIONS [continuing]. And that is I have, and I think most Republicans, have voted for mileage improvements and efficiencies. Many of us have supported, at times, ethanol expansion and those kinds of things because we can do those scientifically, and it makes sense for everybody. So, here is an area that we can agree. And if CO_2 is causing an increase in temperatures, all of these steps will help alleviate it.

Senator BOXER. Absolutely.

Senator SESSIONS. It is just a question of how much we can afford to spend, and that is where the dispute is. Thank you for letting me say that.

Senator BOXER. Well, I like what you just said, and I think there is room for it. So, why do we not continue that conversation together, Senator Sessions. Are you willing to do that, sit down and talk about those various energy efficiencies, fuel efficiencies? All right, we will do it. Thank you very much.

And thanks again to the panel.

We will go to our next panel. We are going to have to do more about the gavel on this one.

Secretary John Griffin, Maryland Department of Natural Resources, Dr. Margo Thorning, Senior Vice President and Chief Economist, American Council for Capital Formation, Dr. Jonathan

Fielding, Director, Los Angeles County Department of Public Health, National Association of County and City Officials.

We are going to have to move this quickly, so if our new witnesses could take their seats. I want to thank them for their patience.

I know Senator Cardin wants to introduce his witness from his State, so why do you not go ahead, Senator Cardin.

Senator CARDIN. Madam Chair, while they are getting situated, let me welcome Secretary John Griffin. He has had a long and distinguished career in our State. He has been one of the architects of the Chesapeake Bay Program that this Committee has heard me talk about on frequent occasions. Maryland has been one of the leaders in developing sensible plans to deal with our environment.

I particularly want to acknowledge the leadership of the O'Malley administration. Secretary Griffin chairs the Adaptation and Response Working Group for the Maryland Commission on Climate Change. We believe that Maryland will give examples of what we can use as a national model to deal with the realities of the new norm on climate change and deal with changes we need to make for public safety and for our future. We are a coastal State, and we need to deal with the risks. And our nation needs to have good policies.

I want to thank Secretary Griffin for being here.

Senator BOXER. Thank you very much, sir.

With that, we will open it up with Secretary Griffin. I am going to use this gavel a little stronger because we have got some meetings at 12:30. So, go ahead.

STATEMENT OF JOHN B. GRIFFIN, SECRETARY, MARYLAND DEPARTMENT OF NATURAL RESOURCES

Mr. GRIFFIN. Chairman Boxer, Senator Cardin, thanks for that kind introduction, distinguished members of the Committee of Environment and Public Works, I am pleased to be here today to discuss with you the importance of taking precautionary, cos effective, and common sense actions now to reduce our vulnerability to the current and future impacts of climate change.

I guess I should also say that I bring warm greetings from Governor Martin O'Malley.

I was asked today to share with this Committee our efforts in Maryland to respond and adapt to the impacts of climate change. Before I do so, though, I wanted to highlight some of the impacts that we are observing and dealing with right now in our State.

Sea level rise. We have documented a sea level rise of 1 foot over the last century due to the combination of land subsidence and global sea level rise, and an additional 3 to 4 feet is projected by the end of this century, increasing our vulnerabilities to strong events, causing more frequent and severe flooding, more shoreline erosion, saltwater intrusion into our drinking water aquifers, and higher water tables.

A recent study you may have seen from the U.S. Geological Survey identified the stretch of coast running from Cape Hatteras to a little bit north of Boston as a hot spot for sea level rise caused by global warming. Since 1990 USGS found that sea levels along

this stretch, which includes, obviously, Maryland, are rising at an annual rate three or four times faster than the global average.

Shoreline erosion. Maryland is currently losing approximately 580 acres of land per year to shore erosion, and alarmingly 13 Chesapeake Bay islands once mapped on nautical charts have already disappeared beneath the water's surface. A 2008 report by the National Wildlife Federation calculated that an additional 400,000 acres of land on Chesapeake's Eastern Shore, that is basically Maryland and Virginia, could gradually be submerged.

Waterfront property along our thousands of miles of tidal shoreline put billions of dollars of public and private investment at risk of loss. For example, approximately 450 State-owned facilities, and close to 400 miles of State highways, are located in areas that are most vulnerable to impacts from sea level rise.

Water temperature increases. Since 1960 the Chesapeake Bay's water temperature has increased 2.8 degrees Fahrenheit. One example of the impact of this change is a decline in eelgrass, an underwater grass that provides critical habitat for fish and juvenile crabs. Scientists expect that eelgrass will very likely be eliminated in the not too distant future from the Chesapeake and our seaside bays because of rising water temperatures.

Impact on Chesapeake Bay restoration. We were also very concerned about the consequences of climate change impacts on the health of the Chesapeake Bay. As shorelines erode, marshes are lost, and forests are flooded, the amount of nutrients and sediments entering the Chesapeake Bay will increase and set us back on our efforts to restore the health of the bay and all the commendable work that Senator Cardin and this Committee have done to help us in the bay region restore the bay.

What is Maryland doing to adapt? In 2007, shortly after he was elected in his first term, Governor O'Malley established the Maryland Commission on Climate Change. The commission about a year later did its original report laying out factions to address not only the drivers of climate change but also how we will adapt and respond to those impacts. Our department, as was mentioned by Senator Cardin, has been leading the adaptation work.

Maryland enacted, in 2009, the Greenhouse Gas Reduction Act which commits the State to reducing greenhouse gas emissions over a baseline of 2006 by 25 percent by 2020. And the Climate Action Plan produced by the Commission also has identified, in two reports, a series of actions that ought to be taken by the State and its local governments to prepare for and adapt to climate change.

Let me just share with you a few of the changes that we are doing at the moment——

Senator BOXER.Doctor, I am going to have to ask you to put those into the record, because we will get to you with the questions.

Mr. GRIFFIN. That is fine. I would be happy to do so.

Senator BOXER. Thank you so much.

[The prepared statement of Mr. Griffin follows:]

Testimony of
John R. Griffin, Secretary
Maryland Department of Natural Resources

before the

U.S. Senate
Committee on Environment and Public Works

August 1, 2012

Chairwoman Boxer and distinguished members of the Committee on Environment and Public Works, it is my pleasure to be here today to discuss with you the importance of taking action now to reduce our vulnerability to the current and future impacts of climate change. State and local governments are at the front lines of ensuring a safe and healthy environment, livable communities, and a sustainable economy. If states and local governments fail to adequately prepare for climatic changes, billions of dollars of federal, state, and local investments in public infrastructure will be threatened.

My testimony focuses on Maryland's long running efforts to research, plan, and prepare for the impacts of sea level rise, extreme storms, and climate change. Our efforts date back to the early 1990's when, in conjunction with the University of Maryland Center for Environmental Science, we began researching the impacts of sea level rise on coastal communities and marsh systems within the Chesapeake Bay. Since then, we have moved from research to planning to actions, and I am honored to be here to share Maryland's progress in adapting to climate change.

The impacts of major concern to our built and natural infrastructure include increased extreme events such as heat waves, droughts, storms, flooding, and forest fires; the spread of existing and new invasive species; and increased erosion and inundation of low-lying areas along the State's extensive shoreline and coast.

Here are some examples of observable impacts that we are already witnessing in Maryland:

- Maryland has experienced more than a foot of sea level rise in the last century due to the combined forces of regional land subsidence and global sea level rise. Current projections from the Maryland Climate Change Commission indicate that we could see as much as three to four feet of additional rise over the next 100 years. A recent study by the U.S. Geological Survey published in the journal *Nature Climate Change*[i] indicates that the 1,000 kilometer stretch of coast running north from Cape Hatteras to north of Boston is a "hot spot" for sea level rise caused by global warming. The study found that since 1990, sea levels along this stretch (which includes Maryland) are rising at an annual rate three times to four times faster than the global average. The impacts of sea level rise are already increasing our vulnerability to storm events, causing more frequent and severe coastal flooding, inundating our low-lying lands, submerging our tidal marshes, and causing more shore erosion, salt-water intrusion, and

higher water tables. Coastal communities are in harm's way, and public funding for disaster relief and restoration will be in increasing demand.

- Maryland is currently losing approximately 580 acres every year to shore erosion; and alarmingly, thirteen Chesapeake Bay islands once mapped on nautical charts have already disappeared beneath the water's surface. A 2008 report by the National Wildlife Federation calculated that approximately 400,000 acres of land on the Chesapeake's Eastern Shore (Maryland and Delaware) could gradually be submerged.[ii] Maryland has thousands of miles of developed waterfront property along its coast, including many historic human settlements such as Smith Island. These coastal areas contain billions of dollars worth of public and private investments that will be adversely impacted by sea level rise and the intensification of coastal storm events. Approximately 450 State-owned facilities and close to 400 miles of State highways are located within areas that will be vulnerable to coastal flooding from sea level rise and/or coastal storms over the next 100 years.

- Since 1960, Chesapeake Bay water temperature has increased approximately in 2.8° F.[iii] Scientists are concerned that eelgrass, an underwater grass that provides critical nursery habitat for commercially and recreationally important fish and blue crab populations, will soon be eliminated from the Chesapeake and our seaside bays because of the rising temperatures and erosion from sea level rise[iv]. Higher temperatures will also very likely increase the size of the Chesapeake Bay's oxygen depleted "dead zone", and the frequency and severity of harmful algal blooms. Fisheries in the Chesapeake Bay will be further stressed by higher surface temperatures and lower dissolved oxygen.[v] These trends pose a real threat to the significant progress we have made toward the recovery of our recreational and commercial fisheries, which contribute more than $1.42 billion to our State's GDP.

- Critical wetland habitat is already being lost to erosion and sea level rise. At least 5,000 acres of Blackwater National Wildlife Refuge have been lost since the 1930s with 300 more acres being lost each year.[vi] Marshes across the Bay are being lost to the same process of erosion and sea level rise and many are not very likely able to keep up, eventually falling apart and sinking into the Bay. Commercially valuable forest lands in other areas of Maryland's Eastern Shore are being lost to flooding. Increased flooding and rising carbon dioxide provide an unfortunate opportunity for invasive species to takeover. All of these impacts affect species such as the saltmarsh sparrow, clapper rail, seaside sparrow, and willet just to name a few.

- Last year, Maryland was hit by Hurricane Irene and Tropical Storm Lee, impacting not only Maryland's coast but also many of our inland towns and communities. Warmer ocean waters will increase the impacts of storms such as these. As residential and commercial development increases on highly prized coastal land, more property will be at risk from intense storms.

- Maryland is one of 28 states across our nation that experienced record high temperatures from July 2011-June 2012. Heat waves in Maryland over the last three summers have been the hottest since 1943, the year of record, and have set one-hundred year records, particularly in urban areas, like Baltimore. In Maryland alone, 13 deaths were attributed to heat in an 11 day period in June and July of this year.

These impacts are resulting in real and documented consequences to the health of Maryland's economy, society, and environment. I am very concerned about the consequences of climate change

impacts to the health of Chesapeake Bay. As shorelines are eroded, marshes are lost, and forests are flooded, the amount of nutrients and sediment entering Chesapeake Bay will increase and set us back in our efforts to restore the health of the Bay.

Due to the observed and increasing future risk that a changing climate poses to Maryland's citizens, ecosystems, and infrastructure, our State is increasingly focused on addressing greenhouse gas emissions and preparing for the impacts of climate change. In 2007, Governor Martin O'Malley signed an Executive Order establishing the Maryland Climate Change Commission, comprised of three working groups – a Scientific and Technical Working Group, a Greenhouse Gas and Carbon Mitigation Working Group, and an Adaptation & Response Working Group. The Governor charged the Commission with developing a plan of action to address both the causes and consequences of climate change.

Approximately a year after its formation, the Commission released Maryland's Climate Action Plan,[vii] setting forth a course of action to address not only the drivers of climate change but also strategies and actions to adapt and respond to the very likely impacts. The work of the Commission resulted in the passage of Maryland's Greenhouse Gas Reduction Act in 2009, which commits the State to reducing greenhouse gas emissions by 25 percent by 2020. We are currently seeking public comment on Maryland's draft plan for achieving the reduction goals set forth in the Act.[viii]

Maryland's Climate Action Plan includes two climate change adaptation strategies which are currently guiding state-level adaptation planning efforts. The first strategy (Phase I), released in 2008, addresses the impacts associated with sea level rise and coastal storms. The second strategy (Phase II), released in 2011, addresses changes in precipitation patterns, increased temperatures, and impacts to human health, agriculture, forest and terrestrial ecosystems, bay and aquatic environments, water resources, and infrastructure.

Following those plans, the Department of Natural Resources established a new policy to direct our investments and land management in order to better mitigate and adapt to climate change. The "Building Resilience to Climate Change" policy outlines practices and procedures related to new land investments, facility siting and design, habitat restoration, operations, research and monitoring, and resource planning. The policy has been instrumental in institutionalizing the following agency practices.

In 2011, DNR made two revisions to its land acquisition strategies. First, we are working to acquire key pieces of land that allow for the landward migration of wetlands in order to provide habitat and important ecosystem services, such as storm surge protection, as sea level rises. Second, we are shifting away from conserving land located in areas less than 2 feet in elevation above mean sea level, as these areas will very likely be under water within the next 50 years.

We are also siting and designing all new facilities and infrastructure to avoid or minimize likely climate change impacts, particularly those associated with sea level rise. A recent example is the new visitor center at Harriet Tubman Underground Railroad State Park in Dorchester County, which will be located outside of the area projected to be vulnerable to sea level rise within the next 50 years and will be elevated 2 feet above the existing 100-year base flood elevation to add extra protection against future coastal flooding. We are currently preparing similar siting and design criteria for all State facilities for consideration as gubernatorial Executive Order in the near future.

Our Department is also working with local governments to encourage sound investments in land and facilities, and to promote the management of natural resources with an understanding of climate change. One such effort is DNR's Coast-Smart Communities Initiative, created to ensure that Maryland's local communities have the tools and resources they need to be ready, adaptive, and resilient to the impacts of coastal hazards and climate change. We also created Maryland's Coastal Atlas[ix], an online interactive mapping tool widely used to access and assess coastal hazard and climate-related data and imagery.

Under the initiative, the Department provides financial and technical assistance to local governments to reduce their vulnerability to the effects of climate change and sea level rise through planning, code revisions, and permitting authorities. To date, the initiative supported hazard resilience projects within 12 of Maryland's 16 coastal counties, which resulted in policy and programmatic changes such as enhanced building codes, and improved floodplain management practices, shore erosion management, and land-use planning. Within the past two years, several local governments including Dorchester County and the cities of Crisfield, Cambridge and Princess Anne, increased the elevation standard for built structures within their tidal floodplains to provide an extra level of flood protection in the event of future sea level rise.

Climate change adaptation planning is happening across all levels of Maryland state government. A few examples include:

- In 2008, the Maryland General Assembly enacted the Living Shoreline Protection Act, requiring non-structural shoreline protection practices in response to coastal erosion and sea level rise. "Living shorelines" include a suite of techniques to minimize coastal erosion and maintain coastal process, while also providing valuable intertidal and near-shore habitat. Living shoreline projects are an increasingly important shoreline management technique, given the additional stressors to Maryland's shoreline from sea level rise, coastal storms and climate change.
- In 2010, the Maryland Department of Housing and Community Development conducted a review of current state-wide building codes and recommended enhancements in coastal regions of Maryland.
- In 2011, the Maryland Emergency Management Agency assessed climate change related hazards, including drought, wildfires, sea level rise vulnerability, storm surge, and shore erosion, and included related hazard mitigation measures in the State Hazard Mitigation Plan.
- In 2012, Maryland activated a State heat emergency web site[x] which includes links to the State Heat Plan, facts about heat related illness, and weekly Heat Reports that provide guidance and information about deaths and illness caused by extreme heat in the region.
- The Maryland Port Administration, State Highway Administration, and Maryland Historic Trust are currently working to assess the vulnerability of the assets, infrastructure and cultural resources that they manage, and to develop and implement adaptation strategies.

The tools and guidance produced through our adaptation initiatives mentioned previously have resulted in the development of a framework for addressing climate change resilience in the planning process across the State. In the context of the reality that we are continuing to grow, live and recreate in areas that are already vulnerable, the State incorporated, "Climate Change Impact Areas" as areas of Special Designation in its' State Development Plan, *Plan Maryland*[xi], released by Governor O'Malley in December of 2011.

Climate Change Impact Areas include areas currently targeted by the Department of Natural Resources for land-use planning and zoning code enhancements, heightened building codes, increased protection, and habitat restoration. They include: the projected 50 and 100-year Sea Level Rise Inundation Zones, 50-Year Erosion Vulnerable Zones, Category 2 Storm Surge Inundation Zones, Marsh Transition Zones, Temperature Sensitive Streams, Drought Hazard, and Wildfire Risk Areas. The intent of these designations is to ensure that the State and local governments make wise decisions about how we protect our natural resources, and where and how we develop and redevelop in light of climate change induced hazards and risks.

The continuation of federal, state, and local government leadership is imperative if we are to continue to adapt to climate change. The Obama Administration should be commended for convening the Interagency Climate Change Adaptation Task Force, co-chaired by the Council on Environmental Quality, the Office of Science and Technology Policy, and the National Oceanic and Atmospheric Administration. The Task Force is working to ensure that federal agencies align their climate change adaptation planning efforts to build a coordinated and comprehensive response to the impacts of climate change on public health, communities, oceans, wildlife, and water resources. The issuance of the *Water Resource Policies and Authorities for Incorporating Sea-Level Change Considerations in Civil Works Programs*[xii] by the U.S. Army Corps of Engineers in July 2009 and updated in November 2011[xiii], and the recent amendments to the National Flood Insurance Program under the Biggert-Waters Flood Insurance Reform Act of 2012 ("Reform Act") also represent great instances of leading by example at the federal level.

Maryland's climate change planning efforts have been advanced in great part due to a number of federal programs and resources. Maryland relies heavily on climate data, observation and synthesis products, decision support tools, technical planning guidance, and training programs provided by federal agencies including the National Oceanic and Atmospheric Administration, the U.S. Environmental Protection Agency, the U.S. Geological Survey, and the U.S. Fish and Wildlife Service. To emphasize this point, we look forward to the release of the "National Fish, Wildlife and Plants Climate Adaptation Strategy" (a collaborative effort between the federal, state, and tribal governments) which we anticipate will serve as an important resource to managers in Maryland working to safeguard our natural resources against the impacts of climate change.

In Maryland, we clearly recognize the need to take action now to prepare for the consequences of climate change. Harnessing nature's ability to adapt and heal itself, we are planting more trees to capture excessive carbon pollution and reduce stormwater and heat impacts, restoring more wetlands and living shorelines to help shield us from flooding and coastal storms, and planning ahead to reduce the vulnerability of Maryland's citizens, infrastructure, and natural resources. As a nation, we must do more to advance our scientific understanding of climate change and reduce our shared societal, economic, and environmental vulnerability to its impacts. We must all continue to advocate for sound planning and strategic actions to avoid or mitigate against the most damaging and likely effects.

For example, coastal wetlands provide a "speed bump" to advancing coastal storms and sea level rise by slowing down and absorbing the damaging effects of waves and storm surges. Similarly, informed land use policies and infrastructure design standards, like those that we are developing in Maryland, can serve as "speed bumps" that mitigate impacts to our built environment.

The challenge before us as we move forward is to accept the fact that the realities faced by our parents' generation are most certainly not the same realities that we face today. We need to learn from the

already observed effects on our built infrastructure and natural resources. We need to recognize the value and resiliency of healthy ecosystems and the services they provide, and we need to adjust our management of our built environment and natural resources accordingly. Doing so is certainly a challenge, but also an opportunity – an opportunity that, if taken advantage of, will ensure the prosperity of our children's and grandchildren's generations.

---

[i] Asbury H. Sallenger Jr., K.S. Doran, P.A. Howd. 2012. Hotspot of accelerated sea-level rise on the Atlantic coast of North America. Nature Climate Change. Published online:
http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate1597.html

[ii] Glick, Patty, et.al.. 2008. Sea-Level Rise and Coastal Habitats in the Chesapeake Bay Region. National Wildlife Federation. Reston, Virginia.

[iii] Boesch. D.F. (ed.). 2008. *Global Warming and the Free State: Comprehensive Assessment of Climate Change Impacts in Maryland.* University of Maryland Center for Environmental Science, Cambridge, MD.

[iv] Najjar, R., C. Pyke, M.B. Adams, D. Breitburg, C. Hershner, M. Kemp, R. Howarth, M. Mulholland, M. Paolisso, D. Secor, K. Sellner, D.Wardrop, R.Wood. 2010. Potential climate-change impacts on the Chesapeake Bay. Estuar. Coastal Shelf Sci. 86: 1–20.

[v] Boesch. D.F. (ed.). 2008. *Global Warming and the Free State: Comprehensive Assessment of Climate Change Impacts in Maryland.* University of Maryland Center for Environmental Science, Cambridge, MD.

[vi] U.S. FWS. 2009. Blackwater National Wildlife Refuge: Marsh loss and restoration.

[vii] Maryland Commission on Climate Change. 2008. Maryland Climate Action Plan. Maryland Department of Environment. Baltimore, Maryland.

[viii] The draft plan is available online at:
http://www.mde.state.md.us/programs/Air/ClimateChange/Pages/Air/climatechange/index.aspx.

[ix] *http://shorelines.dnr.state.md.us/*

[x] http://dhmh.maryland.gov/extremeheat

[xi] Maryland Department of Planning. 2011. PlanMaryland: A Sustainable Growth Plan for the 21st Century. Maryland Department of Planning, Baltimore MD.

[xii] Department of the Army, U.S. Army Corps of Engineers. 2009. Water Resource Policies and Authorities for Incorporating Sea-Level Change Considerations in Civil Works Programs. Circular No. 1165-2-211.

[xiii] Department of the Army, U.S. Army Corps of Engineers. 2011. Water Resource Policies and Authorities for Incorporating Sea-Level Change Considerations in Civil Works Programs. Circular No. 1165-2-212

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Martin O'Malley, Governor
Anthony G. Brown, Lt. Governor
John R. Griffin, Secretary
Joseph P. Gill, Deputy Secretary

January 8, 2013

Senator Barbara Boxer, Chairman
Senate Committee on Environment and Public Works
410 Dirksen Senate Office Building
Washington, DC 20510

Dear Senator Boxer:

Thank you for the opportunity to testify before the Committee on Environment and Public Works on August 1, 2012, at the hearing entitled, "Update on the Latest Climate Change Science and Local Adaptation Measures." It was my pleasure to share with you details on Maryland's long running efforts to research, plan, and prepare for the impacts of climate change.

As noted at the hearing, Maryland is working on the front lines to address the impacts of climate change; impacts that are already resulting in real and documented consequences to the health of Maryland's economy, society, and environment. The State is concerned that climate change will harm efforts to restore the Chesapeake Bay's health and impact billions of dollars in public and private investments, including 400 miles of highways in Maryland. The answers to your recent questions related to my testimony are provided below.

1. How will climate change impact the infrastructure investments we are making now and plan to make in the future?

   The short answer is that by thinking about future impacts today, there is a real opportunity to make wise fiscal decisions to lessen the impacts and economic cost of future extreme weather events and climate change. Unfortunately, the impacts of climate change, including sea level rise, shoreline erosion, and coastal flooding, are already affecting built infrastructure in Maryland and all along our nation's coasts. Between Hurricane Isabel in 2003 and Hurricane Irene and Tropical Storm Lee is 2011, Maryland suffered losses of approximately $92 million. Knowing this and what we do about our vulnerability to climate change, the challenge for the future is to determine how to protect existing infrastructure assets and at the same time working to avoid or reduce future damages by siting and designing new and rebuilt infrastructure projects with climate change and future sea level rise in mind. With this in mind, Maryland has recently passed two pieces of new state policy to address these challenges.

   On December 27, 2012, Governor O'Malley signed the Climate Change and Coast Smart Construction Executive Order (enclosed), enacting a number of policy directives, including

directing all State agencies to consider the risk of coastal flooding and sea level rise when they design capital budget projects and charging the Department of General Services with updating its architecture and engineering guidelines to require new and rebuilt State structures be elevated two or more feet above the 100-year base flood level. The intent of the Executive Order is to ensure that State infrastructure investments in vulnerable coastal areas are fiscally wise and structurally sound.

The State of Maryland also incorporated, "Climate Change Impact Areas" as areas of Special Designation in its' State Development Plan, *Plan Maryland,* released by Governor O'Malley in December of 2011. Climate Change Impact Areas include: the projected 50 and 100-year Sea Level Rise Inundation Zones, 50-Year Erosion Vulnerable Zones, Category 2 Storm Surge Inundation Zones, Wetland Adaptation Areas, High Quality Cold Water Resource Areas, Temperature Sensitive Streams, Drought Hazard Risk Areas, and Wildfire Priority Areas. The State is currently reviewing state funded infrastructure proposals within these areas, as well as targeting them for land-use planning and zoning code enhancements, heightened building codes, increased protection, and habitat restoration.

2. Will adaptation efforts require significant additional investment?

The cost to implement climate adaptation efforts is extremely varied depending on the type or scale of a given adaptation strategy. Adaptation options are often broken down into three broad categories: avoidance, protection, and accommodation. Generalized costs associated with each of these are discussed briefly below.

Avoidance: Adaptation measures aimed at the avoidance of impact can be accomplished with little cost as they are implemented through land-use decision-making processes or through the establishment of siting criteria (i.e., restricting placement of new structures within vulnerable areas). We used this type of adaptation strategy for the proposed placement of the new visitor center at Harriet Tubman Underground Railroad State Park in Dorchester County, which will be located outside of the area projected to be vulnerable to sea level rise within the next 50 years.

Accommodation: Designing infrastructure to accommodate for climate change and sea level rise, such as elevating a structure 2-feet above the 100-year base flood elevation, as required by the Climate Change and Coast Smart Construction Executive Order, will require additional cost, ranging between .25 to 1.5% of the project's construction cost. This cost, however, can be offset in terms of the cost savings over time if inundation or flood damage is reduced avoided.

Protection: The cost to create, protect or restore natural protective barriers such as wetlands, oyster reefs or vegetative dunes could fall anywhere between hundreds of thousands to millions of dollars, depending on the scale of the project. For example, Maryland's annual budget to maintain vegetative dunes on its public ocean front is $2 million ($1 million State/$1 million local). Construction of a man-made storm or surge barrier to protect urban areas, such as Manhattan, will be extremely high and could cost billions of dollars as recently reported by the New York Times. The likelihood of another extreme storm and the subsequent cost of large scale infrastructure damage, human suffering and business interruption will ultimately be a major factor in decisions such as these.

In Maryland, we are undertaking our broad scale climate change adaptation efforts with the understanding that proactive planning now that is geared toward limiting potential future damage is fiscally wise and will in the end, cost much less than acting later.

Thank you again for the opportunity to testify at the hearing on August 1, 2012. I trust that my testimony and the additional information provided in this letter will be helpful as you continue to explore the development of federal policy concerning these important topics.

Sincerely,

John R. Griffin, Secretary

Enclosure:

cc: The Honorable Benjamin L. Cardin, United States Senate
Dana Thompson, Director of Federal Relations, Governor Martin O'Malley
Olivia Campbell Anderson, DNR Legislative Director

The State of Maryland
Executive Department

EXECUTIVE ORDER
01.01.2012.29

Climate Change and "Coast Smart" Construction

WHEREAS, The State of Maryland has the fourth longest tidal coastline in the continental United States and is one of the States most vulnerable to sea level rise – one of the major consequences of climate change;

WHEREAS, Climate forecasters have predicted that the extreme weather events experienced in recent years are indicative of the likely impacts of climate change that the State of Maryland will face in the coming decades;

WHEREAS, The State of Maryland has experienced more than one foot of sea level rise over the last century due to the combined forces of regional land subsidence and global sea level rise;

WHEREAS, The State of Maryland is currently losing approximately 580 acres every year to shore erosion and, alarmingly, thirteen Chesapeake Bay islands once mapped on nautical charts have been lost;

WHEREAS, In July 2012, the U.S. Geological Survey published research in the journal *Nature Climate Change* documenting that over the last 20 years, sea levels along the 1,000 kilometer stretch of coast running north from Cape Hatteras to north of Boston, which includes the State of Maryland, have risen at an annual rate three times to four times faster than the global average;

WHEREAS, Future changes in sea level threaten to increase the State of Maryland's vulnerability to storm events, causing more shore erosion and severe coastal flooding, inundating low-lying lands, submerging tidal wetlands and marshes, and resulting in additional salt-water intrusion and higher water tables;

WHEREAS, The State of Maryland has approximately 450 existing State-owned facilities and 400 miles of roadways within areas likely to be impacted by sea level rise over the next 100 years;

WHEREAS, Billions of dollars of investments in public infrastructure will be threatened if the State of Maryland fails to prepare adequately for climate change;

WHEREAS, The State of Maryland must lead by example by implementing sound planning strategies to avoid or mitigate against the most damaging and likely effects of climate change; and

WHEREAS, The State of Maryland must take action now to ensure that State infrastructure investments in vulnerable coastal areas are "Coast Smart" – fiscally wise and structurally sound.

NOW, THEREFORE, I, MARTIN O'MALLEY, GOVERNOR OF THE STATE OF MARYLAND, BY VIRTUE OF THE AUTHORITY VESTED IN ME BY THE CONSTITUTION AND THE LAWS OF MARYLAND, HEREBY PROCLAIM THE FOLLOWING EXECUTIVE ORDER, EFFECTIVE IMMEDIATELY:

A. Definitions. In this Executive Order the following words have the meanings indicated:

(1) "Base flood" is a flood having a one-percent chance of being equaled or exceeded in any given year; the base flood also is referred to as the 1-percent annual chance (100-year) flood.

(2) "Base flood elevation" is the water surface elevation of the base flood in relation to the datum specified on Flood Insurance Rate Maps. In areas of shallow flooding, the base flood elevation is the highest adjacent natural grade plus the depth number specified in feet on the Flood Insurance Rate Map, or at least four (4) feet if the depth number is not specified.

(3) "Freeboard" is a factor of safety that compensates for uncertainty in factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as wave action, obstructed bridge openings, debris and ice jams, climate change, and the hydrologic effect of urbanization in a watershed.

(4) "Permanent structure" is a structure installed, used, or erected for a period of greater than 180 days.

(5) "Sea Level Rise Vulnerability" is the susceptibility of a coastal area to seasonally high-tides or prolonged or permanent inundation or submergence due to a future rise in water level.

(6) "Special Flood Hazard Areas" refers to land in the floodplain subject to a one-percent or greater chance of flooding in any given year and are designated by the Federal Emergency Management Agency in Flood Insurance Studies and on Flood Insurance Rate Maps as Zones A, AE, AH, AO, A1-30, and A99, and Zones VE and V1-30.

(7) "State structures" are structures planned and built by State agencies that are partially or fully funded with State monies.

(8) "Structure" means that which is built or constructed; specifically, a walled or roofed building, including a gas or liquid storage tank that is principally above ground, as well as a manufactured home.

(9) "Substantial damage" means damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

B. State agencies that propose capital projects for new State structures or the reconstruction or rehabilitation of substantially damaged State structures for inclusion in the State capital budget on or after July 1, 2013, shall consider the risk of coastal flooding and sea level rise to the project and should site and design State structures to avoid or minimize associated impacts.

C. Consistent with applicable law, the Department of General Services shall update its Policies and Procedures Manual for Architecture and Engineering to include guidelines providing that State agencies shall plan construction of all new permanent State structures and the reconstruction or rehabilitation of substantially damaged State structures located in Special Flood Hazard Areas with a minimum of two (2) feet of freeboard above the 100-year base flood elevation, unless the Department of General Services, after consultation with the Department of Natural Resources and the Department of the Environment, determines that a variance from the guidelines is warranted after consideration of the following factors:

(1) The danger that materials may be swept onto other lands to the injury of others;

(2) The danger to life and property due to flooding or erosion damage;

(3) The susceptibility of the proposed structure and its contents to flood damage and the effect of such damage to the State of Maryland;

(4) The importance of the services to the State of Maryland provided by the proposed structure;

(5) The availability of suitable alternative locations that are subject to a lower risk of flooding or erosion damage;

(6) The necessity or benefits of a waterfront location;

(7) The compatibility of the proposed use of the structure with existing and anticipated development;

(8) The need to maintain eligibility or designation as a historic structure as defined by the U.S. Department of the Interior and/or the Maryland Historic Trust;

(9) The safety of access to the structure by passenger and emergency vehicles during a flood;

(10) The expected heights, velocity, duration, rate of rise, and sediment transport of the floodwaters and the effects of any wave action expected at the site;

(11) The costs of providing government services during and after flood conditions, including maintenance and repair of public utilities and facilities such as sewer, gas, electrical, and water systems, and streets and bridges; and

(12) The comments provided by the Maryland Department of Environment and the National Flood Insurance Plan State Coordinator.

D. The Department of Natural Resources, in consultation with the Maryland Commission on Climate Change and/or other relevant parties as necessary, shall develop additional proposed guidelines concerning Climate Change and "Coast Smart" Construction.

(1) Timing. The Department of Natural Resources shall convene a meeting to discuss implementation and recommendations within 45 days of the effective date of this Executive Order and provide an initial report to the Governor within nine months.

(2) Report. The report shall include:

(a) Recommendations for additional "Coast Smart" criteria for the siting and design of new, reconstructed, or rehabilitated State structures, as well as other infrastructure improvements such as roads, bridges, sewer and water systems, drainage systems, and essential public utilities.

(b) Recommendations concerning the potential application of "Coast Smart" guidelines to non-state infrastructure projects that are partially or fully funded by State agencies.

(c) Other recommendations for executive and/or legislative action.

E. The Critical Area Commission for the Chesapeake and Atlantic Coastal Bays should evaluate existing regulations and policies for State Agency Actions Resulting in Development on State-Owned Lands and consider the adoption of new or revised provisions that address climate change and the risk of sea level rise and other extreme weather-related impacts.

F. The Scientific and Technical Working Group of the Maryland Commission on Climate Change shall review the sea level rise projections established by the Maryland Commission on Climate Change published in the Maryland Climate Action Plan (2008) and shall provide, within 180 days of the effective date of this Executive Order, updated projections based on an assessment of the latest climate change science and federal guidance.

G. This Executive Order shall be implemented in a manner consistent with any review or permitting processes that are required by law. This Executive Order does not apply to any federal or local permits or approval processes.

Given Under My Hand and the Great Seal of the State of Maryland in the City of Annapolis, this 28th day of December, 2012.

Martin O'Malley
Governor

ATTEST:

John P. McDonough
Secretary of State

Senator BOXER. Now, I am very proud to welcome Dr. Jonathan Fielding, Director, Los Angeles County Department of Public Health, National Association of County and City Health Officials.

Thank you, sir.

STATEMENT OF JONATHAN FIELDING, M.D., MPH, MBA, DIRECTOR, LOS ANGELES COUNTY DEPARTMENT OF PUBLIC HEALTH, NATIONAL ASSOCIATION OF COUNTY AND CITY HEALTH OFFICIALS

Dr. FIELDING. Chairman Boxer, Ranking Member Inhofe, and members of the Committee, thank you for the opportunity to speak. I am Jonathan Fielding, Director of Public Health and Health Officer for L.A. County, a professor at UCLA Schools of Medicine and Public Health, and I am here also representing the National Association of County and City Health Officials, which is a membership organization comprised of the nation's local health departments. We are the feet on the ground.

Senator Boxer, NACCHO and local health departments across the country recognize and appreciate your leadership on the issue of climate change and its impacts on public health. The city, county, metropolitan, district, and tribal departments work every day to protect residents from all health threats. Some, of course, are very long standing: unsafe water, food. These threats multiply when we have disasters, hurricanes, tornadoes, earthquakes, and wildfires. Local health departments also are responsible for protecting health and minimizing the health effects of many types of acts of terrorism, bio-terrorism, chemical terrorism, and dirty bombs.

We are here because our No. 1 job is to protect the public's health, and it is our responsibility to adhere to the precautionary principle. When we see threats, or threats are very likely, we have to be ready to respond quickly and effectively.

We are currently witnessing the effects of severe storms, droughts, wildfires, and other extreme weather events that cause severe trauma, lead to increases in number of diseases like respiratory disease, to contaminated water and air, and also to mental health. This disproportionately affects the poor, the young, the elderly, and those with physical or mental disabilities.

As you have heard, the past decade was the warmest on record. In 2011 the lower 48 States set temperature records for the warmest spring, the warmest year to date, and the warmest 12-month period since recordkeeping began in 1895. So, we cannot ignore the Intergovernmental Panel on Climate Change conclusion that climate change threatens to "increase the number of people suffering from death, disease, and injury from heat waves, flood, storms, fires, and droughts."

And we cannot ignore the likelihood that climate change will bring us serious vector-borne diseases, mosquitoes and others, that give us dengue fever, Chagas' disease, and other diseases we have not seen before here.

The Federal Government, States, and local health departments all need to adapt to the new and growing risk to critical infrastructure, precious resources, the natural environment, and human health. These affect not only our national health but our national productivity, our competitiveness, and our standard of living.

It has been estimated the costs from six climate-related events from 2006 to 2009 was more than $14 billion. And this figure is an understatement because many of the health effects continue to be felt years after the precipitating event, as many survivors of Hurricane Katrina can attest.

Many health departments have already taken very specific steps. In Los Angeles County, we have enhanced emergency preparedness for increased frequent heat events, and we have conducted vulnerability assessments to identify the most vulnerable populations and are linking them to emergency resources. The Tulsa County Health Department is conducting focus groups after its hottest summer on record in 2011 to help identify vulnerable populations related to respiratory disease, vector-borne disease, and heat related illness, and to modify its Metropolitan Area Health Improvement Plan.

Multnomah County in Portland, Oregon, has completed a vulnerability assessment and is working with a State authority to develop a heat vulnerability index and is testing a Heat Warning and Events Communication Plan. Health departments from all over, and we will put these in the record, East and West Coast, north and south, have all taken action adapting to changes.

So, we cannot afford inaction. I think the threats to climate change effects are basic survival resources; food, water, shelter, and health; and we as local health departments, as your foot soldiers, have to be better prepared.

But despite the threat, preparedness funding for local health departments has been declining. About 55 percent of local health departments saw a decline in their resources in the most recent survey. We need to expand the most recent investment made by the Centers for Disease Control in this area, not reduce it as has been proposed.

And the climate change bill championed by you, Chairman Boxer, addresses the public health role in climate change and the need for a clear action plan at all levels of government. Action is needed now because inaction threatens our public and our national competitiveness.

Thank you very much for the opportunity to appear before you. I would be happy to answer questions.

[The prepared statement of Dr. Fielding follows:]

NACCHO
National Association of County & City Health Officials
The National Connection for Local Public Health

TESTIMONY OF

Jonathan Fielding, MD, MPH, MBA

Los Angeles County Health Department

Update on the Latest Climate Change Science and Local Adaptation Measures

Senate Environment and Public Works Committee

August 1, 2012

Chairwoman Boxer, Ranking Member Inhofe and members of the Committee, thank you for the opportunity to speak to you today. I am Dr. Jonathan Fielding, Director and Health Officer of the Los Angeles County Health Department. I am also here today representing the National Association of County and City Health Officials, a membership organization comprised of the nation's local health departments. These city, county, metropolitan, district, and tribal departments work every day to ensure the safety of the water we drink, the food we eat, and the air we breathe, and to protect every resident from all health threats.

Senator Boxer, NACCHO and local health departments across the country recognize and appreciate your leadership on the issue of climate change and its impacts on the public's health.

Why is climate change a health issue?

Climate change has serious and far-reaching health implications for present and future generations. For example, climate change is already changing the distribution of some infectious disease vectors and according to the Intergovernmental Panel on Climate Change, threatens to "increase the number of people suffering from death, disease and injury from heatwaves, floods, storms, fires and droughts." Climate change may also cause social disruption, economic decline, and displacement of populations, all of which may impact health substantially. Climate change will disproportionately burden some—the very young and the elderly, the physically and mentally disabled, the poor and economically disadvantaged, and other marginalized groups.

The past decade has been the warmest on record, marked by unprecedented flash storms and flooding and the worst drought in Texas' history.[1] The year 2011 saw the lower 48 states set temperature records for the warmest spring, largest seasonal departure from average, warmest year-to-date, and warmest 12-month period, all new marks since records began in 1895.[2] Continuing this trend, the first five months of 2012 were the warmest on record for many locations across the United States and we are

currently witnessing the effects of severe drought, wildfires, and other extreme weather events.[3] In addition to record temperatures, sea levels and temperatures are rising, agricultural zones are shifting, vector-borne diseases are migrating to previously uninhabitable areas, precipitation patterns are becoming more extreme and unpredictable, and extreme weather events are becoming increasingly devastating. All of these issues have ramifications for the health of the communities they affect, including death, injury or trauma, transmission of vector-borne diseases, increased respiratory diseases, contamination of water, and exacerbation of mental health issues.

Changes in the frequency, intensity, or distribution of extreme weather events have posed and will continue to pose a considerable threat to the health of communities across the country. It has been estimated that the health costs of just six climate change-related events from 2002 to 2009 totaled more than $14 billion.[4] As significant as that figure is, these costs do not even fully capture the burden on communities and local health departments as many of the health effects related to extreme weather are often experienced well after the disaster has passed. For example, survivors of Hurricane Katrina continue to experience health issues years after the precipitating event.

The effects of a changing climate are already being felt in many places. Attempting to mitigate emissions to avoid long-term consequences is no longer sufficient to protect human health. The effects of climate change will oftentimes strike hardest where people can least afford to adapt and protect themselves. The Federal government, states, and local health departments all need to adapt to new and growing risks to critical infrastructure, precious resources, the natural environment, and human health.

What is the extent to which local health departments are addressing climate change?

Local health departments are uniquely positioned to prepare for and respond to the health effects of climate change. Communities look to public health for leadership on these issues. Local health departments have the responsibility to anticipate the health burden of extreme weather and climate change, communicate these realities to policymakers and the public, contribute to climate adaptation plans, and create and sustain an all-hazards preparedness capacity.

Some local health departments have begun to increase their capacity to assess and address the health effects of climate change. They are conducting internal needs assessments and vulnerability assessments, training staff, involving diverse strategic partners and community members to incorporate health considerations into comprehensive climate adaptation plans. Additionally, a growing number of local health departments have integrated climate change considerations into emergency preparedness programs in order to increase their effectiveness and maintain capacity. However, since 2008, 50,000 jobs have been cut at health departments and approximately half of local health departments experienced a reduction in workforce capacity during the second half of 2011 alone. Therefore, many local health departments have had to severely cut back on emergency preparedness planning activities due to personnel cuts.

Over the past year, the nation has seen devastating effects from winter storms, tornadoes, floods, and most recently Colorado forest fires. The response to and recovery from these types of tragic events is predicated on having a strong and robust preparedness infrastructure at the local level. Current capacity

must be bolstered to adequately protect the public from the impacts of all natural and manmade disasters, including changing climate, and prevent further health disparities related to their differential impacts.

Budget cuts have compromised the ability of public health departments to build and sustain key partnerships essential to an adequate timely response. In response to these cuts, consolidated planning for all emergencies, including those related to climate change, can help to overcome some of these challenges through the development of strengthened partnerships and more efficient use of limited resources.

What are some examples of what health departments are doing to address climate change?

The Los Angeles County (CA) Department of Public Health is concentrating its climate change response on adaptation strategies. Internally, the Department conducts needs assessments to enhance existing programs' capacities to respond to climate changes, and identifies environmental indicators that allow for increased monitoring and surveillance of changes in the climate. Another component of our efforts is emergency preparedness planning, where we have integrated climate change considerations in order to enhance emergency response. Within our countywide risk, hazard and vulnerability assessment, climate change - particularly adverse heat events - has been highlighted as a focal risk factor. The department conducts vulnerability assessments to geographically identify those most vulnerable to increased heat events (e.g. elderly, disabled, etc) so that we may provide them with information about extreme weather hazards and link them to emergency support resources. Externally, the Department influences local planning and land use decisions in an effort to incorporate climate change into comprehensive plans. We also inform the public of heat events and their impacts through health alerts and advisories.

Beyond the Department of Public Health, the County of Los Angeles has a green purchasing policy that requires County Departments to purchase environmentally preferable products. The County also launched a Reduce, Reuse, Recycle campaign to reduce energy usage, as well as a Ride Share Program to encourage carpooling among its 100,000+ employees. The City of Los Angeles is focusing on mitigation strategies by implementing a Green LA campaign within the city. The action plan calls for a reduction in the city's greenhouse gas emissions to 35% below its 1990 levels by the year 2030.

Other local health departments across the country are also responding to climate change.

- Multnomah County (Portland, OR) has completed a vulnerability assessment related to respiratory disease, vector-borne disease and heat-related illness and is developing an adaptation plan to address these issues. They are working with the Oregon Health Authority to develop a heat vulnerability index and will be testing a heat warning and event risk communication plan targeted to vulnerable populations located in "hot spots" (areas with high urban heat island effect) in an effort to help communities adapt to hotter summers.
- Tulsa (OK) County/City Health Department is conducting focus groups after its hottest summer on record in 2011 to help identify vulnerable populations related to related to respiratory disease, vector-borne disease and heat-related illness and modify its Metropolitan Area Health Improvement Plan

- Clark County (WA) Public Health is conducting a risk assessment to allow it to focus resources in areas of greatest risk. Through partnership with researchers at the University of Washington, it was concluded that in Clark County there is a nearly 20% greater risk of death from respiratory causes on extreme heat days.
- Clark County (WA) Public Health and Thurston County (WA) Public Health and Social Services provided contributions to their local comprehensive city plans that included climate change and health considerations.
- Mercer County (IL) Health Department took the lead on building a coalition with a diverse group of local stakeholders and developing a local climate adaptation plan.
- Orange County (FL) Health Department has trained staff on the health effects of climate change specific to their jurisdiction, including the potential emergence of diseases they do not currently see.
- Mercer County (IL) Health Department and Orange County (Orlando, FL) Health Department have produced educational materials to educate the public on the health risks of climate change and extreme weather. Information has been displayed at County fairs and the Orange County Convention Centers and aired on local television stations.
- Austin/Travis County (TX) Health and Human Services Department conducted a vulnerability mapping exercise that identified several neighborhoods in the City of Austin that were particularly vulnerable to extreme heat or flooding events. Representatives from these neighborhoods participated in a stakeholder committee process.
- Columbus (OH) Public Health, together with Franklin County (OH) Public Health, has developed an extreme heat plan to guide their responses when an extreme heat event occurs.
- New York City Department of Health and Mental Hygiene has implemented a series of programs to address extreme heat events through the development of adaptive capacity in vulnerable areas.

The time for inaction has passed. The intensity of the threat challenges all of our basic survival mechanisms -- food, water, shelter, and health. Local public health departments must play a vital role in addressing climate change. These departments already utilize a multi-level prevention approach that can be applied in responding to climate change.

The climate change bill championed by Chairwoman Boxer addresses the public health role in climate change and the need for an action plan at all levels of government to address the health impacts of climate change. Congress must take action without delay to address this critical issue. The Centers for Disease Control and Prevention, representing the only federal investment in preparing our nation for the health effects of climate change, has provided a small amount of funding over the past few years to quantify the expected health impacts of climate change and support public health department efforts in this area. To assure an adequate response, this investment should be continued and strengthened, not reduced as proposed.

Chairwoman Boxer and Ranking Member Inhofe, thank you for your attention to this important issue. I look forward to continuing to work with you to address this issue with far reaching implications for the future health and quality of life in our nation.

1. Lubber, M. (2012, June 05). Extreme weather is the new reality. Retrieved from http://www.huffingtonpost.com/mindy-s-lubber/climate-changebusiness_b_1567988.html

2. Freedman, A. (2012, June 07). Four major heat records fall in stunning NOAA report. Retrieved from http://www.climatecentral.org/news/warmest-spring-year-and-12-month-period-in-us/

3. National Oceanic and Atmospheric Administration National Climatic Data Center. (2012, June 06). May 2012 national overview supplemental material. Retrieved from http://www.ncdc.noaa.gov/sotc/national/2012/5/ supplemental/page-3/

4. Knowlton, K., Rotkin-Ellman, M., Geballe, L., Max, W., & Soloman, G. (2011). Six climate change-related events in the United States accounted for about $14 billion in lost lives and health costs. Health Affairs, 30(11), 2,167–2,176. doi: 10.1377

COUNTY OF LOS ANGELES
Public Health

JONATHAN E. FIELDING, M.D., M.P.H.
Director and Health Officer

CYNTHIA A. HARDING, M.P.H.
Chief Deputy Director

313 North Figueroa Street, Room 708
Los Angeles, California 90012
TEL (213) 240-8156 • FAX (213) 481-2739

www.publichealth.lacounty.gov

Response to Questions from Senator Barbara Boxer, Environment and Public Works Committee Hearing of August 1, 2012

Question 1: Dr. Fielding, you testified that climate change will disproportionately burden the very young and the elderly, the disabled, and the poor. Could you please describe how vulnerable communities in Los Angeles County and elsewhere are disproportionately impacted by climate change and the key steps that are needed to help address these impacts?

Answer to question 1: A number of physiological, psychological, and socioeconomic factors contribute to the vulnerability of a community to climate change stressors. These factors include a generally higher prevalence of certain diseases, medical conditions, and functional limitations; their higher sensitivity to extreme heat; their increased social isolation; and their financial status. Socioeconomic characteristics, such as income level, access to social and health services, and level of education, can influence the risk of exposure and the capacity to adapt.

Extreme heat waves cause the most harm among elderly people, young children and the poor due to existing medical conditions, higher sensitivity to heat and diminished access to air conditioning. An average of 400 deaths per year are directly related to heat, and an estimated 1,800 die from illnesses made worse by the heat - including heat exhaustion, heat stroke, dehydration, cardiovascular disease, and kidney disease. Heat stroke occurs at rates that are 12 to 23 times higher in persons aged 65 years and older compared with other age groups. Children are at increased risk for morbidity due to a decreased capacity to thermo regulate. Low-income households already face greater health risks and often have diminished access to air conditioning, an important protective factor during heat waves.

Climate change has contributed to a rise in the frequency and severity of extreme weather events - including higher intensity storms and heavier rainfalls. Apart from the obvious risks of direct physical injury or death, extreme weather events lead to a range of secondary health impacts including those that affect the availability and safety of food and water; interruptions in communications, utilities, and health care services; and community disruption and displacement. Transportation access is a critical tool during heat waves and other extreme weather events, allowing individuals to commute to cooling stations, emergency shelters or other safe areas. Emergency transportation is often least accessible to low-income minority communities and individuals with limited mobility.

Climate changes result in more smog and an increase in ragweed and other allergens in the air. Degraded air quality not only impacts individuals with pre-existing respiratory illnesses, but puts many people at risk for irritated eyes, noses, and lungs. This includes outdoor workers, children, the elderly, and those who exercise outside. People with asthma, allergies, and other respiratory

diseases face the most serious threats, since exposure to increased pollution heightens sensitivity to allergens, impairs lungs, triggers asthma attacks, sends people to the hospital, and even results in death. In 2010, the American Lung Association estimated that about 23 million Americans suffered from asthma.

Through its impacts on natural systems, climate change can facilitate the spread or emergence of vector-, water-, and food-borne diseases in areas where they had been limited or had not existed previously. While the water and food-borne outcome of gastrointestinal diseases is mild and self-limiting, they can be severe and even fatal among vulnerable populations, including young children, those with compromised immune systems, and older adults. In a 1985 study, children ages 1-4 years and adults older than 60 years each made up about 25% of hospitalizations involving gastroenteritis, but older adults represented 85% of the associated deaths (U.S. Climate Change Science Program 2008).

Key steps that could be undertaken to reduce the vulnerability and enhance the resilience of Americans to climate change are to reduce Green House Gas emissions by creating active living communities, promoting active transportation and cleaning up our energy choices. Additionally, planning, research and action are needed across the public health sector to prepare for these changes. Resources for local public health departments are needed to build their capacity and enhance resilience at the local level. With adequate resources, local health departments can develop and expand their efforts to address health impacts through cross-sector climate change planning.

Question 2: Dr. Fielding, you cited a November, 2011 study that estimated health costs totaling more than $14 billion from six climate-change related extreme weather events in 2002 through 2009. Can you expand on the burdens that such events place on communities and local health departments?

Within Los Angeles County, the response to any adverse weather event is coordinated by the Office of Emergency Management. It is the responsibility of local health departments to protect health and prevent disease during weather-based emergencies like wildfires, windstorms and floods. The duties involved in these incidents include: increased surveillance and monitoring; public messaging and guidance on protective actions; assistance with shelters/sheltering; and response to various environmental hazards.

During times of extreme heat the County of Los Angeles implements a response for both vulnerable populations and communities at large. Efforts include the opening and monitoring of cooling centers and advisories to ambulances and hospitals regarding preparations to receive patients suffering from the effects of heat. Emphasis is placed on vulnerable populations who could suffer disproportionally as a result of economic or chronic medical conditions. In the 2006 heat wave in California, there were 16,166 excess emergency department visits and 1,182 excess hospitalizations that occurred statewide.

The enduring impacts of extreme storms and floods can be significant. These events can result in contamination of drinking water supplies, disruption of local food production/distribution, increased incidence of indoor mold and associated respiratory illnesses. Exposure to pathogens from sewage and unclean water can sicken vulnerable communities with illnesses like cryptosporidiosis, giardiasis, and norovirus.

Extreme weather events typically result in the loss of power to a community. During these times, wastewater facilities are at greater risk for sewage spills. Without power to treat waste, raw sewage can be discharged into local waters where people swim and play. Local health departments must then take action to protect health by closing beaches and issuing health advisories.

The need to evacuate a region ahead of approaching severe weather can also pose health and safety risks. In particular, logistical issues can hamper the safe evacuation of long-term care facilities. In addition to the challenge of securing appropriate transportation, the evacuating facility must ensure that the receiving facility can manage patients' needs. Successfully moving individuals from nursing and assisted-living facilities to a sheltering facility requires the transfer of essential patient information and resources, including medical records, medications, and medical equipment. This process was particularly problematic and poorly coordinated during the evacuation for Hurricane Katrina (Laditka et al. 2008). During Hurricane Rita in 2005, a bus evacuating elderly nursing home residents from Houston to Dallas was involved in an accident that killed 24 (Houston Chronicle 09/24/2005).

Finally, in addition to above events, local health departments face substantial challenges in the ability to maintain the health of the population due to the loss of housing, drinking water supplies, and access to local food supplies. This makes the population more prone to malnutrition, forced migration, and civil conflict.

Senator BOXER. Thank you very much, Doctor.

And now we hear from our last witness today, and that is Dr. Margo Thorning, Senior Vice President and Chief Economist, the American Council for Capital Formation, as a minority witness.

Welcome.

STATEMENT OF MARGO THORNING, PH.D., SENIOR VICE PRESIDENT AND CHIEF ECONOMIST, AMERICAN COUNCIL FOR CAPITAL FORMATION

Ms. THORNING. Thank you, Chairman Boxer, Ranking Member Inhofe. I appreciate the chance to appear before you today to discuss some of the challenges and some of the opportunities that the business community has in adapting to the potential climate variability or climate change.

First, some of the challenges. The climate models that we have seen predicting change out over the next 50 to 100 years vary greatly, not only in terms of where the change in temperature or the change in precipitation may occur, but also when. So, the climate models are not sufficiently precise to allow business to make good plans for the future.

Second challenge is that the business community tends not to plan more than 3 to 15 years in advance unless you are in a business like utilities where your capital stock may last 40, 50, 60 years. So, the general business plans are not able to make—take account of the fact that climate change may occur but may not be significant for 50 or 100 years. So they will tend to adopt what we call no regret strategies which are changes that they would make in the normal course of doing business.

A third barrier or a third challenge for the business community to adapting to climate variability is regulatory policy and permitting delays. For example, the regulations, the EPA's regulation of greenhouse gases under the Clean Air Act is estimated to slow investment spending in 2014 by $25 billion to $75 billion and reduce GDP significantly and also hinder job growth, perhaps 500,000 to 1.4 million fewer jobs. That slows economic growth, makes it more difficult for the economy to provide the resources to provide for adaptation to climate change.

Now, the opportunities for the business community to adjust to climate change are certainly there. Many companies are adopting no regrets strategies, as I mentioned, strategies that they would do anyway. For example, in agriculture, figuring out developing seeds that are more drought resistant or more resistant to increased weather variability.

So, many industries are already adjusting suppliers and thinking about what the potential impact is. But these are changes they would do as a normal course of business. They are not responding to threats that may be out there 50 to 100 years.

Other industries like utilities are beginning to do what we call hard adaptation. They are beginning to change the way they—change the installation of their transmission lines, their distribution lines. For example, Intergy, the big company, a big energy company on the Gulf Coast, is spending $75 million to harden its transmission and distribution lines to a major port because of expe-

rience with extreme weather. So, they are actually going beyond no regrets strategies.

But the main thing that probably would assist companies in adapting to the potential threat of climate change is making sure we maintain strong economic growth because with that we can afford to make the changes that may be necessary. One component of maintaining strong growth is making sure that our tax code continues to preserve strong capital formation initiatives. As we debate tax reform, we need to be sure that any reform that is put in place does not weaken the incentives for new investment.

And even going beyond lowering corporate rates, as both the Simpson Plan and others have suggested, we ought to be thinking about switching to a consumed income tax. A joint tax committee research, as well as research by Allen Sinai of Decision Economics, shows that if the U.S. were operating under a system where all savings is deductible and all investment is expensed, we would have faster economic growth, more investment, faster job growth, and it would enhance our ability to adapt to climate change.

The last point is the need to reform our regulatory process, to make sure regulations meet the cost-benefit test so that they do not unduly burden our ability to invest and to grow, and to reform the permitting process.

I also want to add that when you think about small and medium-sized enterprises, if climate change does occur they will face even greater challenges than do large scale operations. So, we need to be very careful that we preserve the kind of incentives that enable the U.S. economy to grow and make the changes that might be necessary.

Thank you.

[The prepared statement of Ms. Thorning follows:]

Adapting to Climate Change: What are the Challenges and Opportunities for the U.S. Business Community?

By
Margo Thorning, Ph.D.
Senior Vice President and Chief Economist
American Council for Capital Formation
Before the
Committee on Environment and Public Works
U.S. Senate

August 1, 2012

Executive Summary

Current Climate Models Produce Conflicting Results: The wide variation in temperature, rainfall and other measures predicted by the various climate models makes it difficult for both policymakers and the private sector to decide when and how much capital to invest in measures to adapt to possible changes in the climate. Business investments are judged on the basis of their costs and benefits so until climate models show more convergence, the business community will have difficulty in justifying adaptation policies beyond "no regrets" (or those that would be undertaken anyway in the normal course of business).

Most Businesses Do Not Plan Investments over Long Time Horizons: Many climate models do not predict significant global warming for at least another 50 to 100 years; their simulations commonly extend to the year 2100. Most businesses however, plan investments over a 3 to 15 year horizon, not 50 to 100 years. Thus, business is more likely to engage in "no regrets' strategies to address adaptation to climate variability rather than undertake substantial investments in anticipation of changes in climate that may only occur in 50 to 100 years.

Barriers to Investment Caused by Regulatory and Permitting Delays: Conflicting regulations, regulatory uncertainty and permitting delays are often factors hindering U.S. companies from making investments to improve or expand their facilities in order to adapt to extreme weather events or climate variability. For example, in addition to permits to meet federal regulations there are often additional state and local permit requirements which add time and cost to a project getting underway. EPA regulation of GHGs under the Clean Air Act is an example of regulatory uncertainty that is likely to be slowing not only adaptation but also U.S. investment and job growth.

Opportunities for Business to Adapt to Potential Climate Variation: U.S. companies have already begun to adopt "no regrets" strategies to adapt to climate change. For example, some utilities are "hardening" their infrastructure to reduce damage from future weather events and agriculture and the insurance industry are also developing technologies and policies to adapt to climate change.

Financing Adaptation Will Depend on Strong Economic Growth: Sound fiscal policies and a tax code that retains robust capital cost recovery rules can enhance growth. Further serious consideration should be given to a consumed income tax in which all saving is deducted and all investment is expensed. Regulatory reform and reducing permitting delays will also enhance growth .

Adapting to Climate Change: What are the Challenges and Opportunities for the U.S. Business Community?

By
Margo Thorning, Ph.D.
Senior Vice President and Chief Economist
American Council for Capital Formation
Before the
Committee on Environment and Public Works
U.S. Senate

August 1, 2012

Introduction

Chairman Boxer, Ranking Member Inhofe and members of the Committee, my name is Margo Thorning, senior vice president and chief economist, American Council for Capital Formation (ACCF),* Washington, D.C. I am pleased to submit this testimony on challenges faced by the private sector in adapting to both near and long term variations in climate.

The American Council for Capital Formation represents a broad cross-section of the American business community, including the manufacturing and financial sectors, Fortune 500 companies and smaller firms, investors, and associations from all sectors of the economy. Our distinguished board of directors includes cabinet members of prior Democratic and Republican administrations, former members of Congress, prominent business leaders, and public finance and environmental policy experts. The ACCF is celebrating over 30 years of leadership in advocating tax, regulatory, environmental, and trade policies to increase U.S. saving, investment and job growth.

Background

Adapting to changes in the climate has been a feature of life for the ecosystem including humans, animals and plants for millions of years. In recent years, increased concentrations of greenhouse gases (GHGs) in the atmosphere have raised concerns that the earth's temperature may warm to levels which will cause increased extreme weather events, decreased rainfall, rising sea levels, more rapid loss of species and other changes that would cause economic and environmental damages. My testimony focuses on the economic and financial issues that need to be understood

*Founded in 1973, the *American Council for Capital Formation is a nonprofit, nonpartisan organization advocating tax, energy, regulatory and environmental policies that facilitate saving, investment, economic growth and job creation. For more information about the Council or for copies of this testimony, please contact the ACCF, 1750 K Street, N.W., Suite 400, Washington, D.C. 20006-2302; telephone: 202.293.5811; fax: 202.785.8165; e-mail: info@accf.org; website: www.accf.org*

and addressed in order for the U.S. business sector to begin to address the risks that may arise if global temperatures rise significantly in the future.

Challenges for Business in Adapting to Potential Climate Change

- **Current Climate Models Produce Conflicting Results**

The wide variation in temperature, rainfall and other measures predicted by the various climate models makes it difficult for both policymakers and the private sector to decide when and how much capital to invest in measures to adapt to possible changes in the climate. Several factors make climate modeling challenging: (1) uncertainty about emissions trajectories, (2) uncertainty about how the climate responds to changes in GHGs in the atmosphere and (3) natural climate variability due to factors such as solar activity and volcanic eruptions. A recent presentation by Professor Jouni Raisanen of the University of Helsinki highlights the extreme variation in temperature predictions produced by modeling 7 simulations using 22 different climate models.[1] As shown in Figure 1, the temperature changes predicted by 2069 to 2098 range from 1 to 7 C. Furthermore, absolute differences in the various models' predictions for changes in temperature and precipitation increase with the passage of time (see Figure 2). In addition, the models are not granular enough to even allow a reliable estimate of the impacts on southern compared to northern Texas so it is difficult for a company to know what to react to. Business investments are judged on the basis of their costs and benefits and therefore until climate models show more convergence, the business community will have difficulty in justifying adaptation policies and investments beyond "no regrets" steps (or those that would be undertaken anyway in the normal course of business).

- **Many Businesses Do Not Plan Investments over Long Time Horizons**

Many climate models do not predict significant global warming for at least another 50 to 100 years; their simulations commonly extend to the year 2100. Most businesses however, plan investments over a 3 to 15 year horizon, not 50 to 100 years. As noted by David Cotts and Edmond Rondeau in *The Facility Manager's Guide to Finance and Budgeting*, 'few firm's strategic plans extend beyond ten years and many are capped at five."[2]

Further, a recent OECD report, *Private Sector Engagement in Adaptation to Climate Change* states that:

> "Risk assessments vary based on companies' capabilities and priorities – some countries use dedicated tools to assess climate risks while others broaden the scope of existing risk management procedures to include climate change. The incorporation of longer time frames into risk assessments to capture long-term climate change risks is not yet common. The possible increase in frequency and intensity of extreme events is often the

[1] http://www.baltex-research.eu/ecosupport/events/uncertainty_workshop_2010/Jouni_Raisanen.pdf

[2] http://books.google.com/books?id=lbPM1Q4WrWIC&pg=PA47&lpg=PA47&dq=business+planning,+how+far+out+to+plan,+industry,+10+years&source=bl&ots=xX9a7_Flm1&sig=IEbP6ViSm-rW-sX2f7OwV4_3MTo&hl=en&sa=X&ei=9ZEWUPqjJOXn0gH14oCwCA&ved=0CF4Q6AEwAQ#v=onepage&q=business%20planning%2C%20how%20far%20out%20to%20plan%2C%20industry%2C%2010%20years&f=false

main focus of risk assessments, and companies are generally more concerned about direct impacts than about indirect impacts."[3]

It seems likely that in the absence of clear evidence about the scale and timing of damage from climate variability, companies will continue to wait to make major investments until after a significant event such as a storm or flood occurs. In addition, the rapid change in business conditions, technology and global competition in recent years makes businesses cautious about making assumptions about the future profitability of investments. Thus, business is more likely to engage in "no regrets' strategies to address adaptation to climate variability rather than undertake substantial investments in anticipation of changes in climate that may only occur in 50 to 100 years.

- **Barriers to Investment Caused by Regulatory and Permitting Delays**

Conflicting regulations, regulatory uncertainty and permitting delays are often factors hindering U.S. companies from making investments to improve or expand their facilities in order to adapt to extreme weather events or climate variability. For example, in addition to permits to meet federal regulations there are often additional state and local permit requirements which add time and cost to a project getting underway.

An example of a regulation that is likely to be slowing U.S. investment for maintenance and expansion as well as for "no regrets" and "hard" investments to adapt to climate change is the U.S. Environmental Protection Agency's regulation of U.S. greenhouse gas emissions under the Clean Air Act (CAA). EPA began requiring regulated stationary sources with emissions over a specified emissions threshold to obtain permits under the Prevention of Significant Deterioration (PSD) and Title V Operating Permit programs in 2011. The PSD program requires that new and modified facilities of entities such as power plants, industrial and commercial boilers, iron and steel producers, refineries, cement and pulp and paper producers having the potential to emit greenhouse gases above a certain level must obtain a preconstruction air quality permit. The Title V program requires sources having the potential to emit air pollutants above a certain amount to obtain an operating permit. In order to obtain a PSD permit, regulated emitters will have to put in place "Best Available Control Technology" (BACT). In November 2010, EPA released general guidelines for selecting BACT; the selection will be done on a case-by-case basis. Unfortunately the BACT guidelines are not likely to materially reduce the uncertainty facing regulated entities planning capital investments or improvements and thus the factors that impact the cost of capital and investment hurdle rates will continue to impede the U.S. economic recovery.

As a result of the uncertainty caused by EPA's GHG regulations, investment is estimated to decline by 5% to 15 % in directly impacted industries, such as the electric power sector, mining, manufacturing and wholesale and retail trade which were responsible of 25% of overall capital investment in U.S. economy in both 2008 and 2009. A 5% to 15% decline in investment for only the directly affected industries would result in an approximately $25 to $75 billion reduction in investment outlays and could result in between 476,000 to 1.4 million fewer jobs in 2014

[3] http://www.oecd-ilibrary.org/docserver/download/fulltext/5kg221jkf1g7.pdf?expires=1343662341&id=id&accname=guest&checksum=AB5A1E60DAE2A2CF7BF18F5E957CD1E8

compared to the baseline forecast.[4] In addition, GDP would be $47 billion to $141 billion less in 2014 than compared to the baseline forecast.[5]

Another example of U.S. regulatory and permitting policies delaying new investment which could help business reduce emissions as well as adapt to climate change is found in recent testimony by Hal Quinn of the National Mining Association. He notes that slow permitting is hindering investment in domestic rare earth mines.[6] (Rare earth minerals have many industrial uses including for catalytic converters and in the nickel-metal hydride batteries used in hybrid cars). Quinn states that the United States Geological Survey recently reviewed permit times for U.S. metal mines and found that "The time to obtain a permit has required as many as 17 years and one mine the Pogo, Alaska gold mine, was developed under an expedited permitting schedule that still took 7 years."[7]

The interim report of the President's Council on Jobs and Competitiveness also recognizes the role that U.S. regulations and permitting delays play in delaying or preventing new investment. The report's policy recommendations include: (1) requiring agencies to develop a template for online permit tracking for federal permitting and environmental review, (2) requiring agencies to seek early stakeholder engagement and holding agencies accountable for meeting permitting milestones, (3) limiting duplication among local, state and federal agency reviews and (4) improved up-front processes in permit approvals that could be helpful in litigation management.[8]

Opportunities for Business to Adapt to Potential Climate Variation

- **"No Regrets" Planning for Adaptation**

The OECD report cited carried out 16 case studies on a variety of companies in different industries regarding their policies and plans for adapting to climate change. Many focus on direct and immediate impacts that may already be evident, such as more frequent and violent natural hazards, rather than more distant and uncertain systemic risks.[9]

The case studies also reveal that companies' engagement in implementing risk management measures varies. Having assessed climate change impacts on their business operations, some companies may decide not to implement adaptation measures, or to delay implementation. This can be part of an efficient adaptation strategy if the expected benefits of those measures are outweighed by the costs on a present value basis.

Two third of the companies in the OECD survey have implemented "no regret" activities that can be classified as adaptation, but which they would have implemented in any case for other purposes. These measures usually deal with current climate variability and current environmental

---

[4] http://accf.org/wp-content/uploads/2011/02/House-Energy-Commerce-Testimony-292011-FINAL.pdf
[5] Ibid., p, 5.
[6] http://www.nma.org/pdf/cong_test/042612_quinn.pdf
[7] Ibid., p.3.
[8] http://files.jobs-council.com/jobscouncil/files/2011/10/JobsCouncil_InterimReport_Oct11.pdf
[9] Ibid., p. 28.

concerns, or are measures that are beneficial to the companies' business operations while also making them more resilient to climate change impacts. Examples of such synergistic measures can be found in several industry sectors and typically address issues of water scarcity, sustainable agriculture, the climate resilience of suppliers and sources of raw materials for production, and market-driven changes in customer demand. [10]

- **Going Beyond "No Regrets" with Climate Preparedness**

While not yet widespread, some companies in the U.S. are moving beyond "no regrets" policies by planning for climate change as well as investing in "hard adaptation" measures. As the OECD report explains, hard measures include specific technological and infrastructural changes involving capital goods that consider specific climate change risks in planning and design. The selection of specific measures will depend on the extent and type of changes that the company has to make in order to be climate proofed.

For example, as a result of damage from Hurricanes Rita and Katrina and awareness of climate risk to the Gulf Coast, a major utility company, Entergy Corporation has begun a $74 million dollar project to relocate and harden transmission and distribution lines serving Port Fourchon, Louisiana which is the single largest point of entry for crude oil coming into the U.S. [11]

Similarly, the agriculture industry is also beginning to plan for the possibility of a warmer world as well as for the expected 30 % increase in food production needed by 2050 to feed the world's growing population. Some regions and crops could do better, thanks to a longer growing season and higher levels of CO2 in the air, and others could suffer. Seed companies have renewed their efforts to develop drought resistant crops, according to John Soper, director of product development at Pioneer, a unit of DuPont.

"We're expecting some drier weather to move into the key corn growing areas," he said. "The climate in Illinois might be more like the climate in Arkansas." Pioneer is testing drought-resistant corn and other crops in desert-like test fields in California and Chile, he said, in part because farmers who now irrigate their fields are already telling Pioneer that they expect limits on the availability of water. In India, Pioneer is working to develop drought-tolerant varieties of rice, which is now grown on flooded land but may have to adapt to a drier climate. Other seed companies including Monsanto, Syngenta and Bayer Crop Science are working on their own drought-resistant crops.[12]

The insurance industry is also recognizing that more extreme weather events may occur in the future. Insurance, which is society's traditional risk management tool, will have a role to play in addressing the impacts of floods, hurricanes, fires, tornados or other events. As a recent report by Zurich Financial Services Group notes, insurers have the tools to play a significant role in widespread adaptation to the possible risks resulting from climate change. For example, insurers have had success in supporting the deployment of building code requirements and new technologies. Insurers could again play that role in facilitating adaptation to climate change risk

[10] Ibid., p.29.
[11] http://www.marcgunther.com/2012/01/22/climate-change-its-time-to-get-ready/
[12] Ibid.

– through coverage provisions related to resilience of building stock and infrastructure to extreme weather events.[13]

Strong Economic Growth Can Facilitate Adaptation to Climate Change

Adapting to variations in the climate will be easier for countries that whose economies are growing and for businesses and consumers which are prospering. In order to finance both "no regrets" investments as well as hard adaptations to climate variability businesses will need strong portfolios and growing assets. Among the policy options that should be considered to enhance U.S. economic growth are tax reform. In addition, as discussed above, reducing regulatory and permitting barriers to new investment will also promote a stronger economy.

- **Tax Policy to promote U.S. investment and economic growth**

As policymakers debate tax reform, they need to consider how important cash flow is for new U.S. investment. New academic research provides evidence of the strong link between investment and cash flow; a dollar of current and prior-year cash flow is associated with $0.32 of additional investment for firms that are least likely to face difficulty in raising money in capital markets and with $0.63 of new investment for firms likely to face constraints. These results have implications for U.S. investment and job growth since ACCF research shows that each $1 billion in new investment is associated with an additional 23,300 jobs (see Table 1).[14]

Some tax reform plans such as Bowles/Simpson trade accelerated and bonus depreciation for a lower corporate income tax rate. If these provisions are repealed and replaced with economic depreciation which is generally longer than the current Modified Accelerated Cost Recovery System (MACRS), the cost of capital for new equipment will rise and investment is likely to decline. The benefit of MACRS and bonus depreciation is its positive impact on cash flow, which occurs immediately as the investment is put in place. If, as seems likely, higher hurdle rates were to cause U. S. investment in equipment (which averaged $1.1 trillion in 2011) to decline, there would be a significant negative impact on employment and economic growth.

Instead of making some segments of the business community better off at the expense of others by eliminating tax provisions such as accelerated and bonus depreciation or LIFO in order to "pay for" lower corporate tax rates, under any tax reform policymakers should retain or enhance capital cost recovery rules in order to promote new investment and economic growth. Better still, they should consider a consumed income tax in which all saving is deducted and all investment is expensed. Dr. Allen Sinai, president and chief global economist of Decision Economics, used his large scale macroeconomic model to simulate the impact of a consumed income tax compared to the federal tax code in effect in 2001. The simulation modeled a system in which all saving is tax exempt, all new investment is written off in the first year, and interest expense for business and individuals is not tax deductible. The consumed income tax simulation shows strong increases in GDP, investment, employment, and federal tax receipts compared to the baseline forecast. If the consumed income tax system had been in place starting in 1991,

[13] http://www.zurich.com/sitecollectiondocuments/insight/climateriskchallenge.pdf

[14] http://accf.org/wp-content/uploads/2012/07/ACCF-Testimony-7-27-2012-FINAL1.pdf

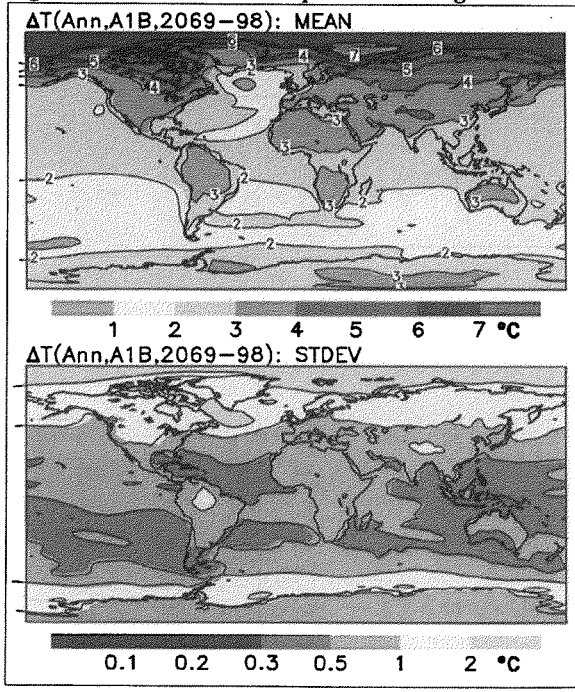
GDP would have been 5.2 percent higher, consumption and investment would have been greater, and employment higher by over 140,000 jobs per year by 2001 (see Table 1). In addition, federal tax receipts would have been $428.5 billion larger in 2001 compared to the baseline forecast. [15]

Conclusions

Climate models are still in the development stage and the various models yield significantly different predictions about future temperature and precipitation. Accordingly, for companies which rely on cost/benefit analysis to guide their investment decisions, a policy of "no regrets" will continue to shape their approach to adaptation to climate change. In addition, adapting to variations in the climate will be much easier for countries and businesses which have the resources to invest in new technology, new products and innovations across all sectors. Strong U.S. economic growth can be promoted through sound fiscal policies and a tax code that promotes economic growth with robust capital cost recovery rules. Further, serious consideration should be given to replacing the current income tax system with a consumed income tax which is favorable to saving and investment. Reducing regulatory and permitting barriers will also help restore much needed investment across all sectors.

[15] Ibid.

Figure 1. Annual Mean Temperature Change from 1971-2000 to 2069-2098

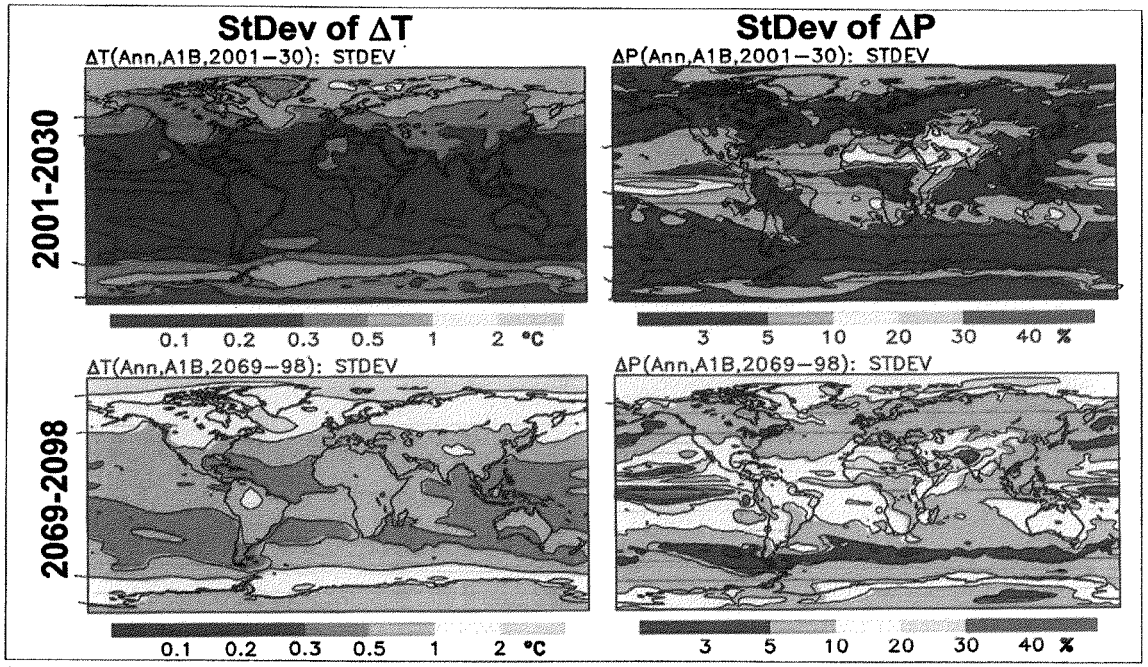


22-model mean temperature change (top) generally much larger than the **standard deviation** between the simulations (bottom).

Both are largest over the Arctic

Source: Uncertainties in Projections of Climate Change, Jouni Raisanen, 14 October 2010, http://www.baltex-research.eu/ecosupport/events/uncertainty_workshop_2010/Jouni_Raisanen.pdf

Figure 2. Absolute Differences between Climate Models' Estimates of Temperature and Precipitation Increase with Time



Source: Uncertainties in Projections of Climate Change, Jouni Raisanen, 14 October 2010, http://www.baltex-research.eu/ecosupport/events/uncertainty_workshop_2010/Jouni_Raisanen.pdf

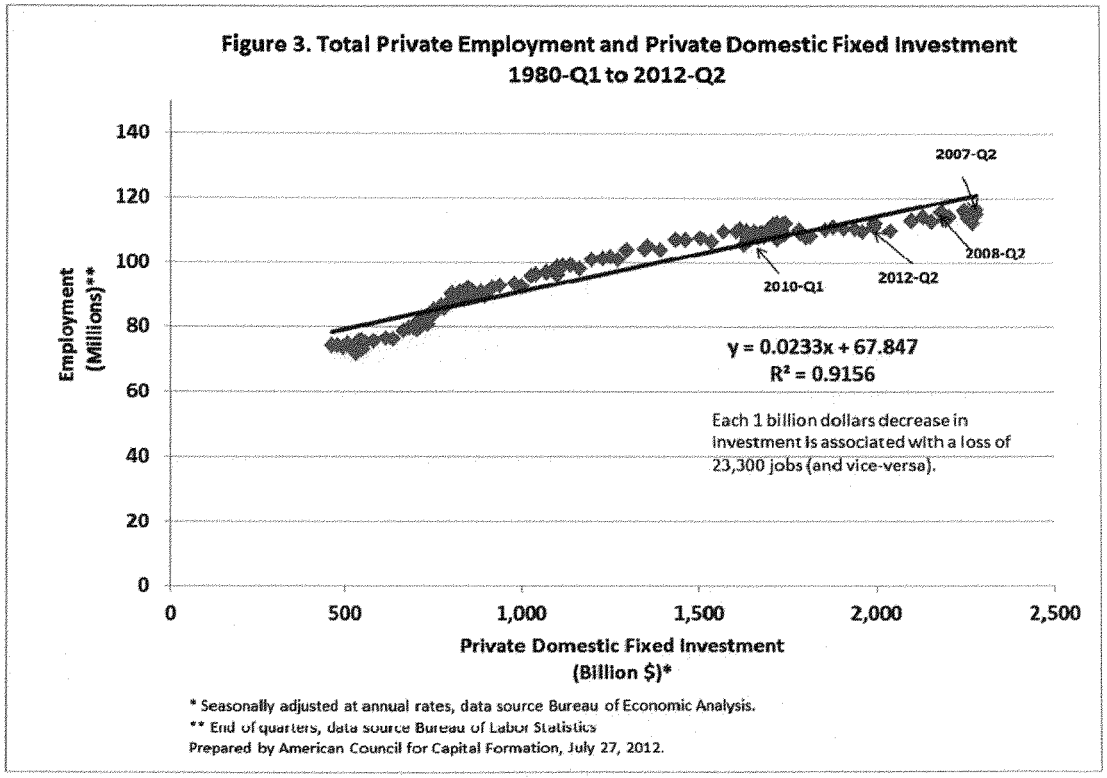


Figure 3. Total Private Employment and Private Domestic Fixed Investment
1980-Q1 to 2012-Q2
Employment (Millions)**
140
120
100
80
60
40
20
0
0
500
1,000
1,500
2,000
2,500
Private Domestic Fixed Investment (Billion $)*
2007-Q2
2008-Q2
2010-Q1
2012-Q2
y = 0.0233x + 67.847
R² = 0.9156
Each 1 billion dollars decrease in investment is associated with a loss of 23,300 jobs (and vice-versa).
* Seasonally adjusted at annual rates, data source Bureau of Economic Analysis.
** End of quarters, data source Bureau of Labor Statistics
Prepared by American Council for Capital Formation, July 27, 2012.

Table 1 **Economic Impact on the United States of Switching to a Consumption Tax in 1991**
Expensing business investment, removal of the business and personal interest deduction, and tax exemption of savings

	Average 1991–1995	Average 1996–2000	Average 2001–2004
Real GDP—level (billions of 96$)			
Base	7,085.8	8,499.6	10,113.1
Simulation of consumption tax	7,203.2	8,890.0	10,637.7
(Difference in level)	117.5	390.5	524.6
(Percent change in level)	1.7%	4.6%	5.2%
Business capital spending, total (billions of 96$)			
Base	684.2	1,092.0	1,599.6
Simulation of consumption tax	824.9	1,495.6	2,168.8
(Difference in level)	140.7	403.5	569.2
(Percent change in level)	20.6%	37.0%	35.6%
Consumption (billions of 96$)			
Base	4,761.7	5,717.2	6,746.3
Simulation of consumption tax	4,773.3	5,843.4	7,021.5
(Difference in level)	11.6	126.1	275.3
(Percent change in level)	0.2	2.2	4.1
S&P 500 Price Index			
Base	449.1	1081.9	1803.2
Simulation of consumption tax	557.4	1370.5	2123.4
Difference	108.4	288.6	320.2
(Percent difference in level)	24.1%	26.7%	17.8%
Employment (millions of persons)			
Total payrolls, base	111.8	125.8	138.5
Total payrolls, simulation of consumption tax	111.8	129.3	140.9
(Difference in level)	0.0	3.6	2.4
Productivity (annual percent change)			
Nonfarm business, base	1.5	2.7	2.3
Nonfarm business, simulation of consumption tax	2.6	2.8	2.8
Difference	1.1	0.1	0.5
Total federal tax receipts			
Base	6,210.5	8,853.2	9,179.3
Simulation of consumption tax	5,745.5	8,821.0	9,607.7
(Difference in level)	-465.0	-32.2	428.5

Source: See Margo Thorning, "U.S. Capital Formation: How the U.S. Tax Code Discourages Investment", http://www.ipi.org/ipi_issues/detail/us-capital-formation-how-the-us-tax-code-discourages-investment using data from Allen Sinai, "Macroeconometric Model Simulation With the Sinai-Boston Model of the U.S. Economy," unpublished study, 2001.

Senator BOXER. Thank you.

I am going to take some time to ask Dr. Thorning a set of questions. Then I am going to turn to Senator Inhofe. He can ask whoever he wants, and then I will get back to the rest.

Dr. Thorning, I found your testimony really interesting since you are a minority witness, and I just—I guess I need to know what is your role in the American Council for Capital Formation? What is your responsibility in that organization?

Ms. THORNING. Helping to guide the research that we undertake, helping to explain to media, to the public, to policymakers what the economic consequences of various policy shifts might be.

Senator BOXER. And yet you said that—it seemed to me that you were sort of saying that companies are getting ready for the impacts of climate change already. Is that correct?

Ms. THORNING. My understanding is companies are taking it into account. They are beginning to do no regrets strategies.

Senator BOXER. What does that mean, no regrets?

Ms. THORNING. That means, for example, if you are a seed producer you would be trying to develop seeds that could withstand drought or could withstand increased rainfall or increased——

Senator BOXER. So that you will not regret the lost opportunity to do this.

Ms. THORNING. And presumably whether the climate shifts sharply or not, you still would be better off.

Senator BOXER. Great point. Great point.

Ms. THORNING. It is my understanding that they are undertaking policies that will enable them to sustain their business and also potentially be ready for what may come in terms of climate.

Senator BOXER. Well, I am going to quote you from now on because I think we need to do a no regrets strategy here. This is a break through moment because what you basically said is that—see if I am interpreting it right—you are not positive when this happening, although I did read your testimony, it looks like you have embraced the fact that changes are coming and may not come for a few decades, but they are coming. But instead of wasting this time, you are going to take steps in case the worst happens. That is how I am looking at it.

Ms. THORNING. I think most prudent businesses would be looking ahead. They try to anticipate the best they can what the future may hold. But the main point of my testimony is that most businesses do not really make hard investment decisions beyond a 3- to 15-year time horizon, and the long, long term projections for climate change are simply beyond what they normally can incorporate in their business plan. But they will, where they can, adopt no regrets strategies.

Senator BOXER. OK. Now, does the American Council for Capital Formation have an opinion on climate change?

Ms. THORNING. We stick pretty much to the economics. I defer to your expert panel on climate change.

Senator BOXER. OK, because I know some of your sponsors are the Koch brothers, the ExxonMobil, other oil companies, the American Petroleum Institute. But they are part of a long list of businesses, is that correct?

Ms. THORNING. That is correct. We are supported by a wide range of industries in the financial sector, insurance sector, as you can see on our Web site.

Senator BOXER. Well, I want to thank you for your testimony because to me, I think these businesses are being very prudent. They are embracing a no regrets strategy. They see that this could happen, it could accelerate, it may not, they say, but it could and they are doing things right now to prepare.

And that is all I think we ought to do here as a nation, prepare. Because, as you pointed out in your testimony, I thought quite eloquently, Dr. Thorning, that the things that you are doing are good, good for the businesses. If they do, for example, create a seed that helps you get through a drought period, we all know there are going to be drought periods even if there is no intensification of that drought period. They are going to be prepared.

So, I am going to take your lesson, this leadership in the private sector, to address this problem and bring it here to this Committee and see whether we cannot find some more support for moving forward to have a no regrets type of strategy. I really appreciate your bringing that terminology into this debate.

Thank you.

Senator INHOFE. Well, thank you. First of all, I will have to, I hate to do this but I will have to leave as soon as I ask my questions because I told the Chairman I have a serious problem outside.

Let me ask you to put four things in the record that I think are important as a result from the testimony from the first panel. One is the—from the NASA report that says that in 2011 saw 9,000 Manhattans of ice recovery, and we are talking here about the Arctic. The second one would be a peer reviewed paper, the American Geophysical Union found a doubling of snow accumulation in the western Antarctic peninsula since 1950.

The third would be a reviewed article in the climate, the Journal of Climate, that examines the trend of sea ice extending the east Antarctic coast from 2000 to 2008 and finds a significant increase of 1.3 percent per year. And last, Greenland, since it was mentioned, even the IPCC recognized that the ice sheet is growing at 2 inches a year.

So these four things I would like to have made a part of the record.

Senator BOXER. We will in fact do that.

[The referenced information was not received at time of print.]

Senator INHOFE. I would only say the last conversation, and the questions that were asked of you, Dr. Thorning, that there is a big difference between could happen and will happen. I think a lot of companies—and I came from the private sector, we do things, we try to anticipate. If something could happen, we want to be ready for it. Not that it will happen. There is a big difference.

Now, over the years you have testified that the costs of cap and trade, and I would suggest after perhaps one of the members to my left might want to introduce another cap and trade bill because I can assure you that it would not pass. In fact, less than one-third of the U.S. Senate would be voting for it.

You have talked about the costs of cap and trade. I have talked about the costs of cap and trade. Now, a lot of us are anticipating

and suggesting a carbon tax. Tell me, economically, how that would affect our country, a carbon tax?

Ms. THORNING. Well, putting a tax on a commodity like energy will certainly raise prices and probably negatively impact U.S. competitiveness. If we are going to do any kind of tax policy, as I said in my testimony, I think we should be looking at switching to a consumed income tax where all investment is deductible, and all saving is tax exempt, and what is the tax base is consumption. That would be consumption of everything, energy, food, high priced cars, et cetera.

So, I would suggest the best approach to helping the U.S. economy grow, which will help it adapt to whatever comes down the path, is to switch to a broad based consumption tax.

Senator INHOFE. All right. I can remember before this Committee when Director Lisa Jackson was making her testimony, and I asked the question, if we were to pass, at that time I believe we were talking about the Waxman-Markey bill—but it did not make any difference because cap and trade is cap and trade—would this reduce, if we passed it, worldwide CO_2 emission, and she said, of course, no, it would not. And I appreciated her honesty.

I also remember, I think it was either 2005 or 2006, is when a change took place. We used to be a larger emitter of CO_2 than China. That all changed in, I think it was in 2006. Today, and we have a chart that shows this, China has gone up so that it now has doubled the CO_2 emissions than that of the United States.

So, I would like to ask you the question, economically, if this trend continues, what is going to happen, what is going to be—how does it affect us, our manufacturing base and our economy in this country?

Ms. THORNING. Let me be sure I understand the question. What happens if China's emissions continue to grow? Or what happens if we try to cap our own emissions?

Senator INHOFE. Well, you would be capping our own emissions if we do because we are talking about doing that, either a carbon tax or something else.

Ms. THORNING. Oh, I see. Well, because of the global trend, the rest of the world emissions growing so much faster, ours actually declined from 2006, I think capping emissions here will have virtually no impact on global concentrations.

In fact, EPA released a figure back when they were debating the Waxman-Markey bill that showed that even if the U.S. met the targets in the Waxman-Markey bill by 2050, it would make almost no difference of GHGs.

So, I think measures like cap and trade in the U.S. would be counter-productive, it would slow our growth, we would not be able to make the changes that might be needed to adapt because our growth would be so much slower. So it would be counter-productive.

Senator INHOFE. And I appreciate that. That is essentially what the director of the EPA said in response to the question.

The last question I have is, you mentioned that as a result of the uncertainty caused by the EPA's greenhouse gas regulations, business investment is expected to decline by 5 to 15 percent, and directly impact industries, which could result in 476,000 jobs to 1.4

million fewer jobs in 2014. Is it fair to say that eliminating EPA's authority to regulate greenhouse gases would save these jobs?

Ms. THORNING. I think scaling those back would definitely reduce some of the uncertainty faced by the business community. The business community faces uncertainty from the healthcare bill, Dodd-Frank, debt ceiling, tax reform, as well as environmental regulations. So, anything we can do to reduce uncertainty would tend to encourage investment. And investment, non-residential investment, is still down about 6 percent compared to the fourth quarter of 2007.

Senator INHOFE. Yes. And if you—I am sure that you have, but you might share with us your thoughts on this. When we had cap and trade legislation, they were talking about how much greenhouse gas should, could, under those be reduced. However, if you look at doing this through an endangerment finding and doing it through regulations, that amount would actually have to go down far below what was found in any of the cap and trade bills to be consistent with the Clean Air Act. And that would have been down to, I think, 25,000 as opposed to something, what, 250,000.

How much greater effect would that have on our economy that just cap and trade?

Ms. THORNING. Well, it would be significantly greater because almost all facilities of any size at all would have been impacted, and it would hinder investment and hinder even continued operation for many, many companies.

Senator INHOFE. Thank you very much.

Senator BOXER. Thank you, Senator.

So, here is the situation. I need to go to a leadership meeting. I am going to put something in the record, I am going to thank everyone, I am going to hand the gavel to Senator Cardin, and he can call, after he is done, on Senator Sessions and then if Senator Cardin can close this down.

I just want to put into the record late breaking news from CNN, more than half of U.S. counties now disaster zones due to drought. So, this no regrets strategy that Dr. Thorning has put forward should be embraced by everybody—business, the Federal Government, and I know, particularly, in States like Maryland that are already seeing an impact.

[The referenced information was not received at time of print.]

Senator BOXER. So, I am going to turn the gavel over. I want to thank everyone from the bottom of my heart.

Senator CARDIN [presiding]. Senator Boxer, thank you very much.

I just really want to respond very briefly to Senator Inhofe. The efforts that we have engaged in Congress with Senator Lieberman and Senator John Warner, Senator Kerry and Senator Boxer, in order to take responsible steps to deal with climate change, was not aimed at what was happening in the United States alone, but was aimed at joining the international community so that the chart that we just saw in regards to China, you could also put one in regards to India, that it would be fair competition globally with internationally efforts.

So I just really wanted to set the record straight as to the efforts. It was aimed, yes, at the United States, energizing our economy,

energizing our business leaders to come up with solutions to climate change, but also doing it in context of the international community.

Secretary Griffin, I want to get to the issues of adaptation, and I really do applaud Governor O'Malley and the O'Malley administration for taking a real leadership position on realities of adaptation, on dealing with the new norm, and that is extreme weather. We cannot tolerate the type of disruptions we had just a few weeks ago with the storms and people being out of power for over a week in 100 degree weather.

I know that Governor O'Malley has taken certain steps. The consumers have a right to better information than they had during this storm. It is not right to call a number and get a recording saying that your power is going to be back that evening and find out 3 days later that you still do not have power. People needed to have good information.

So, is the Governor, in part of his work, working with our utilities to establish a better service response to these types of, now I think more frequent, storms?

Mr. GRIFFIN. Yes, Senator Cardin. This actually started a few years ago due to other weather related power outages around our State. And he has been working with the Public Service Commission. Just, I think last week, he issued another Executive Order forming a team of government, science, and utility experts to start to look at how we build more reliability into our distribution systems for electric power.

So we are doing all that we can. It is not easy. Certain issues we are looking at, such as the pros and cons of burying utility lines, are fairly daunting and costly, but nonetheless the Governor seems very committed to gradually improving in a variety of ways the reliability of our distribution system.

Senator CARDIN. And I would urge him also to get, to require our oversight for better information so people know what the likelihood is of restoring power.

I want to get to some of the challenges we have at sea level, our State being a coastal State, and some of the action that we have already taken. I have visited Smith Island. I know what is happening at Smith Island and the loss of land and people trying to save their homes and their businesses.

I was at the Naval Academy when we had the storm and the flooding, and I saw the damage that was done. And I see the projections if we go up sea level what is going to happen to that type of facility. And it is not easy to retro do the type of work that is necessary.

I know that you have made certain commitments as it relates to the Tubman Park Visitor Center, to put it above the flood plain which I think is the right type of policies we need to have for adaptation. So we plan today, recognizing that sea level is changing, and that we take steps to protect the shorelines from that type of damage. We have done work in Ocean City in order to protect against the increased flooding.

What do you see as coming out of the task force that you are working with to deal with the unique problems we have being a coastal State?

Mr. GRIFFIN. Those are all very legitimate points, Senator Cardin. I think I would view it in the largest sense as we are on a continuum of learning and taking, I think, prudent actions. An ounce of prevention now, certainly in my view, history, in our view, history teaches us is far superior than allowing these problems to build and build when the cost of remediation is far greater.

I think we are doing, not only in Maryland but through RGGI, the Regional Greenhouse Gas Initiative, with other States and also an effort regionally with States from New York down through Virginia called MARCA. The Governors of those States signed a series of MOUs back in 2009 to start looking at ocean policy, and one of the key issues there was climate change and our ability regionally to adapt to it.

So, a number of things are unfolding. A number of our coastal counties we have been working with with Federal support, thankfully, are starting to do the sort of work we are going statewide. We are assisting them with the tools. As you alluded to, better building codes, identifying the most vulnerable areas to try to reduce from the land use standpoint, further major development and investments there.

So, those sorts of things are going on across the State actually, particularly in our coastal areas which is where most of our people live, reside.

Senator CARDIN. Thank you very much. I appreciate that.

Senator Sessions.

Senator SESSIONS. Thank you.

As we wrestle with these issues I think we have to be realistic or, I think, fair. With regard to drought and floods, this morning we have had advocates say that floods are caused by global warming gases and droughts are caused by global warming. Whatever happens, the advocates say it is caused by global warming.

Well, maybe both can be. But the data I have seen so far does not indicate that. The chart I showed earlier indicates we are not having more extreme highs or lows in the last 60 years than we have had previous to that.

Also looking at a chart on U.S. drought, since 1900 the patterns have not really changed. Last year was a pretty high drought year, but the year before that was a very low drought year, or 2 years before that, and it is pretty much the same pattern that we have had.

Dr. Thorning, let me run a few things by you as an economist. It seems to me that, in an economic sense, passing a law that requires the business to community and private homeowners to spend large amounts of money to "go green" is no different than the Federal Government taxing the economy and the Federal Government paying to fix up people's homes to make them more "green." Would you agree?

Ms. THORNING. Yes.

Senator SESSIONS. It may be slightly more efficient to let the individuals figure out how to do it themselves, but in an economic sense, we are burdening the economy when we ask people to do things that are not in their economic interest, correct?

Ms. THORNING. Yes, I agree. I would like to add to that. In previous testimony, I noted that States that have renewable portfolio

standards, which I believe 30 States do have, tend to have household and industrial electricity prices that are about 30 percent higher than States without renewable portfolio standards.

So, that is something to think about because that is a mandate that probably is not going to do much to slow global warming, but yet it imposes a very real cost, especially on low- and middle-income people.

Senator SESSIONS. I remember a number of years ago we were losing our chemical industry in Alabama, and I know Ohio and other States were losing that industry, too, because of high natural gas prices. Natural gas prices have dropped dramatically, and I believe it is providing an incentive to the economy in creating jobs as a result of lower cost energy making us more competitive. Would you agree?

Ms. THORNING. Yes. And in fact, if you look at the recent new plants being installed by our chemical industry, by the steel industry, and other industries that are dependent on either low feedstock prices or low electricity prices, you can see the positive impact that our increased production of natural gas in the U.S. has had on the overall economy.

Senator SESSIONS. Now, we want to have higher wages, as high wages as we can possibly afford for our workers. But if we burden our workers with unnaturally high energy prices, it not only hurts the business, but it hurts the employees who are part and parcel of that commercial enterprise, correct?

Ms. THORNING. Well, if you are spending more on electricity and energy you have less money to spend on other things, which means the economy, there is a contraction there. And productivity is not enhanced by raising energy prices.

Senator SESSIONS. Now, Alabama has had some success in attracting investment: foreign investment, automobiles, steel, chemical, as examples. And when an industry looks at a State, is it not a fact that they consider energy prices very much in deciding where they might place a plant?

Ms. THORNING. It certainly is an important factor.

Senator SESSIONS. So, the extent to which we raise artificially energy costs, higher than they would be based on the normal market forces, we diminish the growth potential in our economy, do we not?

Ms. THORNING. Yes. And in fact, studies that the ACCF has sponsored over the years on Waxman-Markey and the Kerry-Lieberman bills demonstrate a significant impact on job growth and competitiveness compared to the baseline forecast.

Senator SESSIONS. I just have to say that I am excited about low cost natural gas. I think that has provided us an infusion of money to our manufacturing sector and is going to create jobs. And if we can keep prices down, we will be better off. And to mandate costs that are not justifiable can create financial impacts on the people that are subject to the mandates. And that does hurt us economically. There is just no doubt about that in my mind.

So, we try to strike the right pattern, Mr. Chairman, in which some of the regulations can actually make us be leaner, more efficient, more productive, while some of them add costs and make us less efficient, less productive, and cost jobs.

Thank you.

Senator CARDIN. Thank you, Senator Sessions. And thank the second panel for your patience and your testimony.

As was pointed out at the beginning of this hearing, this was going to be a lively discussion, and it was a lively discussion. And I agree with Senator Inhofe. I would hope that we would have more of these opportunities to debate these issues.

So, I really want to thank you for adding to today's record as we look at not just the science, but what steps are necessary for adaptation as we go through different weather patterns and climate patterns here in America.

We can argue the cause, we can argue a lot of issues. But the facts are the facts, and we need to take the appropriate steps in order to protect the public safety and the economy of America.

I want to acknowledge Mitch Hescox with the Evangelical Environmental Network and the Young Evangelicals for Climate Action who are also here with us today. We welcome you here.

And with that, the hearing will be adjourned.

[Whereupon, at 12:45 p.m., the Committee was adjourned.]