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(III)
THE COSTS OF CLIMATE CHANGE: RISKS TO THE U.S. ECONOMY AND THE FEDERAL BUDGET

TUESDAY, JUNE 11, 2019

HOUSE OF REPRESENTATIVES, COMMITTEE ON THE BUDGET, Washington, D.C.

The Committee met, pursuant to notice, at 10:00 a.m., in Room 210, Cannon House Office Building, Hon. John A. Yarmuth [Chairman of the Committee] presiding.

Present: Representatives Yarmuth, Moulton, Doggett, Schakowsky, Kildee, Panetta, Morelle, Horsford, Jackson Lee, Jayapal, Omar, Peters, Cooper; Woodall, Johnson, Smith, Flores, Holding, Stewart, Norman, Roy, Meuser, Timmons, Crenshaw, Hern, and Burchett.

Chairman YARMUTH. Good morning and welcome to the Budget Committee’s hearing on The Costs of Climate Change: Risks to the U.S. Economy and the Federal Budget. I want to welcome our witnesses here with us today.

This morning we will be hearing from Dr. Katharine Hayhoe, professor of political science and director of the Climate Science Center at Texas Tech University; Dr. Solomon Hsiang, professor of public policy at UC Berkeley, and a visiting scholar at Stanford; Mr. Alfredo Gómez, director of the natural resources and environment team at GAO; and Mr. Oren Cass, senior fellow at the Manhattan Institute.

We will now begin with opening statements, and I yield myself five minutes.

Good morning. As we said, this Committee has come to order. I would like to welcome everyone to the Budget Committee’s hearing on the impacts of climate change on our nation’s economy and federal budget. I would like to thank our witnesses also for joining us today.

This is a hearing on the future of the country, covering a topic that we cannot afford to ignore. Americans are already feeling the effects of climate change: homes have been blown away in hurricanes that are increasing in intensity, or lost to wildfires that are spreading farther and taking longer to extinguish. Our farmers have endured prolonged droughts, while some states have experienced historic flooding.

The Intergovernmental Panel on Climate Change’s October report warned that, if greenhouse gas emissions continue at the current rate, our atmosphere will continue to warm with dangerous
consequences. In addition to more destructive storms, wildfires, and droughts, we will experience increasingly acidic oceans, a loss of wildlife, reduced air quality, increased disease exposure, and a drastic decrease in crop production, among other disasters that could permanently reshape our way of life.

Climate change is an environmental issue, it is a public health issue, it is a national security issue. And, as we will talk about today, it is increasingly an economic and fiscal issue. It is my hope that, when faced with the data and testimony of our esteemed witnesses, we can separate opinion from fact, and acknowledge that, as a governing body, we must plan for the consequences of a changing climate if we are to avoid future catastrophe.

Last November the fourth National Climate Assessment Report was released, and it painted a dire picture for our future. It concluded that not only is the evidence of human-caused climate change overwhelming, its consequences are intensifying. If no mitigating action is taken, climate change will increasingly wreak havoc on the U.S. economy, human health, and the environment.

For example, between 2005 and 2014 we spent an average of $36 billion annually responding to extreme weather and fire events. But that level of spending looks tame, compared to where we are headed. For 2018 alone, Congress appropriated more than $130 billion for disaster-related purposes. And all indications are that these costs will continue to dramatically rise in the years and decades ahead, if no action is taken.

Already, billions of dollars of federal property and approximately half of all U.S. military sites are threatened by climate change. That is not my assessment; that is from the Pentagon’s Initial Vulnerability Assessment Report on climate-related risks to DoD infrastructure. Major assessments from the Climate Impact Lab and EPA’s Climate Change Impacts and Risk Analysis Project also concluded that, if we continue business as usual with high emissions and limited resilience efforts, annual losses across multiple sectors of our economy could exceed $500 billion, or roughly 3 percent of national GDP, by the end of the century.

The global investment management company BlackRock estimates that the median risk of commercial properties being hit by a category four or five hurricane has increased by more than 135 percent since 1980. This increase could further rise to 275 percent by 2050, with major implications for commercial mortgage-backed securities. They also add that “extreme weather events pose growing risks for the credit worthiness of state and local issuers in the $3.8 trillion dollar U.S. municipal bond market.”

The only people who fail to understand the seriousness of climate change are the Trump Administration and some of our Republican colleagues. If they are not moved by environmental, health, and security consequences, I hope the economic costs and the impact on the federal budget will get their attention, because we cannot afford to wait for them to catch up. We can’t afford to be the only country that is not part of the historic Paris climate agreement. We can’t afford to have an Administration that continues to deny climate change, and handicap the agencies and programs responsible for responding to it, making the problem far worse and, ultimately, more costly.
It is our responsibility, as the Budget Committee, to review the issues that threaten our fiscal health and our constituents. Without serious action to address climate change, federal spending will continue to rise on everything from federal disaster response to flood insurance, crop insurance, and federal facility preservation and repairs, not to mention the increased public health costs.

I hope today’s hearing will make clear that we must rejoin our global partners in tackling the threat of climate change, and commit to substantial reductions in carbon pollution, meaningful investments in clean energy, and policies that strengthen our communities and prioritize the health and safety of current and future generations.

[The prepared statement of Chairman Yarmuth follows:]
Good morning, this hearing will come to order. I’d like to welcome everyone to the Budget Committee’s hearing on the impacts of climate change on our nation’s economy and federal budget. I’d like to thank our witnesses for joining us today.

This is a hearing on the future of our country, covering a topic that we cannot afford to ignore. Americans are already feeling the effects of climate change. Homes have been blown away in hurricanes that are increasing in intensity or lost to wildfires that are spreading farther and taking longer to extinguish. Our farmers have endured prolonged droughts, while some states have experienced historic flooding.

The Intergovernmental Panel on Climate Change’s October report warned that if greenhouse gas emissions continue at the current rate, our atmosphere will continue to warm with dangerous consequences. In addition to more destructive storms, wildfires, and droughts, we will experience increasingly acidic oceans, a loss of wildlife, reduced air quality, increased disease exposure, and a drastic decrease in crop production – among other disasters that would permanently reshape our way of life.

Climate change is an environmental issue. It’s a public health issue. It’s a national security issue. And, as we’ll talk about today, it’s increasingly an economic and fiscal issue.

It is my hope that when faced with the data and the testimony of our esteemed witnesses, we can separate opinion from fact and acknowledge that as a governing body we must plan for the consequences of a changing climate if we are to avoid future catastrophe.

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For example, between 2005 and 2014, we spent an average of $36 billion annually responding to extreme weather and fire events. But that level of spending looks tame compared to where we are headed. For 2018 alone, Congress appropriated more than $130 billion for disaster-related purposes – and all indications are that these costs will continue to dramatically rise in the years and decades ahead if no action is taken. Already billions of dollars of federal property and approximately half of all U.S. military sites are threatened by climate change. That’s not my assessment – that’s from the Pentagon’s initial vulnerability assessment report on “Climate-
Related Risk to DoD Infrastructure.” Major assessments from the Climate Impact Lab and EPA’s Climate Change Impacts and Risk Analysis project also concluded that, if we continue business as usual with high emissions and limited resilience efforts, annual losses across multiple sectors of our economy could exceed $500 billion, or roughly three percent of national GDP, by the end of the century.

The global investment management company BlackRock estimates that the median risk of commercial properties being hit by a category 4 or 5 hurricane has increased by more than 135 percent since 1980. This increase could further rise to 275 percent by 2050, with major implications for commercial mortgage-backed securities. They also add that “Extreme weather events pose growing risks for the credit worthiness of state and local issuers in the $3.8 trillion U.S. municipal bond market.”

The only people who fail to understand the seriousness of climate change are the Trump Administration and some of our Republican colleagues. If they are not moved by environmental, health and security consequences, I hope the economic costs and the impact on the federal budget will get their attention -- because we cannot afford to wait for them to catch-up. We can’t afford to be the only country that is not part of the historic Paris Climate Agreement. We can’t afford to have an Administration that continues to deny climate change and handicap the agencies and programs responsible for responding to it - making the problem far worse – and ultimately more costly.

It is our responsibility, as the Budget Committee, to review the issues that threaten our fiscal health and our constituents. Without serious action to address climate change, federal spending will continue to rise on everything from federal disaster response, to flood insurance, crop insurance, and federal facility preservation and repairs – not to mention the increased public health costs. I hope today’s hearing will help make clear that we must rejoin our global partners in tackling the threat of climate change and commit to substantial reductions in carbon pollution, meaningful investments in clean energy, and policies that strengthen our communities and prioritize the health and safety of current and future generations.
Chairman YARMUTH. And now—just made it under my five minutes.

Anyway, I now yield to the Ranking Member, Mr. Johnson, for his opening statement.

Mr. Johnson. Well, thank you, Chairman Yarmuth. And I am going to try and fill some really big shoes, and attempt to give an opening statement on behalf of our Ranking Member, who is in Appropriations this morning.

But I would first like to request unanimous consent that his prepared opening statement be submitted for the record.

Chairman YARMUTH. Without objection.

[The prepared statement of Steve Womack follows:]
Thank you, Chairman Yarmuth, for holding this hearing. I look forward to the testimony and debate on this important topic.

As you know, Mr. Chairman, we cannot have a discussion about how to address climate change without looking at the leading solution proposed by your side of the aisle: the Green New Deal, which has been sponsored by almost 100 of our Democratic colleagues and adopted as a centerpiece of the progressive agenda.

This is now the second hearing we have held featuring solutions with more government control and less freedom for Americans.

Last month, we held a hearing on imposing a one-size-fits-all, single-payer health care system, as Democrats’ Medicare-for-All proposal would do. Now we’re having a hearing on the Green New Deal.

I’m looking forward to learning what’s next on our docket.

Since we are on the Budget Committee – and we have a responsibility first and foremost to consider the dangers of growing our nation’s debt – let’s start by looking at the cost of the Green New Deal.

According to a former Congressional Budget Office director, the Green New Deal is projected to cost $33 trillion over ten years. This figure is more than four-and-a-half times what our nation’s GDP was in 2018.

What does that enormous price tag mean for a family of four in my district?

About $60,000 in higher costs and bigger taxes each year. To put that number in perspective, that’s just under the median household income in the United States, which is less than $61,500 a year.

Just like our hearing last month, I look forward to learning from many of the Green New Deal co-sponsors about how they plan to pay for a $33-trillion proposal. If you’re a believer in Modern Monetary Theory, you may not think we need to pay for it at all – a concerning position to take when you’re supposed to be managing our debt.

With the stated goal of fully transitioning away from fossil fuels and nuclear power, the Green New Deal includes: establishing complete renewable electricity generation; mandating zero-emission passenger vehicles by 2030; making every building in the country energy efficient; and transitioning to high-speed trains, which would essentially eliminate air travel.
Not only will these policies fundamentally change how Americans heat and cool their homes, commute to work, and travel across the country or around the world. They will also substantially increase energy costs – harming low-income families the most – and end millions of jobs across the economy, including those in the energy, manufacturing, transportation, and agriculture sectors.

Workers across the country are starting to raise red flags over how the Green New Deal will impact their jobs. They recognize that this level of government interference threatens their ability to make a living and provide for their families.

What you are not likely to hear from my colleagues across the aisle is that the United States is leading the world in reducing greenhouse-gas emissions.

In fact, in 2017, carbon emissions were the lowest they have been since 1992 – not because of government regulations, but because of the ingenuity of our local communities and businesses.

As the architects of the Green New Deal wrote in an FAQ handout, this proposal is “a massive transformation of our society.”

How many of our constituents really want this radical upheaval of their lives? Especially when you consider the fact that our country cannot effectively address climate change alone. Reducing greenhouse-gas emissions is a global issue.

Congress should focus on policies that build on our progress – not sweeping overhauls of our economy that would stifle competition and innovation, add trillions of dollars to our nation’s debt, and fail to achieve our shared objective: protecting the environment.

We should continue efforts to break down regulatory barriers that stand in the way of developing more energy-efficient, cost-effective technology. We should encourage investments in carbon capture, renewable hydropower, safe nuclear power, and energy storage. And we should continue to promote research into these renewable sources.

It is my hope that we can work together on market-based solutions that make clean energy more affordable and reliable, create jobs, and address climate change.

With that, Mr. Chairman, I yield back.
Mr. JOHNSON. As you have heard, the title of today’s hearing is, “The Cost of Climate Change: Risks to the U.S. Economy and the Federal Budget.” But we can’t have a hearing about climate change without taking a detailed look at the favored proposal among our colleagues on the left: The Green New Deal.

Currently, the Green New Deal has 93 cosponsors, about a dozen of whom serve on the Budget Committee. Following our hearing last month on Medicare for All, this is our second hearing featuring a central plank of the progressive agenda. I will be curious to learn what the focus will be at our next hearing if we continue down this path.

We are supposed to be the Committee of fiscal discipline, the Committee that is responsible for managing and addressing our nation’s debt. But instead of talking about a budget, something Democrats were unable or unwilling to produce, we are here to discuss a $93 trillion proposal that has been hailed on the left as a massive transformation of our society. “Transformation,” in this case, should be replaced with “upheaval” to make the description more accurate.

The proposal has been billed as the cure to our environmental challenges. In reality, it would dump tens of trillions of federal dollars into new programs and mandates on families, businesses, states, and localities that will increase energy costs, raise taxes, eliminate jobs, and fail to actually address climate change.

The U.S. has been a leader in reducing greenhouse gas emissions, but we cannot effectively address climate change alone. This is a global issue. China and India accounted for half the increase in global emissions in 2017, the same year that U.S. carbon emissions were the lowest they have been since 1992.

Congress should focus on policies that encourage research and development of all sources of energy, such as carbon capture and sequestration, energy storage, small modular nuclear reactors, or hydropower, to name a few. We should break down regulatory barriers to innovation and promote competition with the goal of making clean energy more affordable, accessible, and reliable, creating jobs, and growing the economy. In doing so, America will continue to lead other countries in reducing our impact on our climate, without adding to our nation’s debt and disrupting the lives of American workers and families.

Innovation is the cornerstone of America. It is what we do best. But more government interference and less freedom for Americans is the wrong policy to get the results we want.

I do want to add that it is not entirely fair to say that there are no ideas on how to pay for the astronomical cost of the Green New Deal. The concept of modern monetary theory has been cited as a solution to all our debt problems because, so the theory goes, the government can just print more money to pay our bills. Now, I am skeptical of that claim, but I understand that Chairman Yarmuth made some news on this topic in an interview at the Peterson Foundation Fiscal Summit this morning. I am hopeful a hearing on this theory is on the horizon.

Thank you again Mr. Chairman, and I yield back.

[The prepared statement of Bill Johnson follows:]
Vice Ranking Member Bill Johnson (R-OH) Opening Remarks at Hearing on Climate Change

Remarks As Prepared For Delivery:

Thank you, Chairman Yarmuth. I’m going to attempt to fill the shoes of our distinguished Ranking Member and give an opening statement, but I’d first like to request unanimous consent that his prepared opening statement be submitted for the record.

The title of today’s hearing is “The Costs of Climate Change: Risks to the U.S. Economy and the Federal Budget”. But, we can’t have a hearing about climate change without taking a detailed look at the favored proposal among our colleagues on the Left: The Green New Deal. Currently, The Green New Deal has 93 co-sponsors – about a dozen of whom serve on the Budget Committee.

Following our hearing last month on Medicare-for-All, this is our second hearing featuring a central plank of the progressive agenda. I’ll be curious to learn what the focus will be at our next hearing if we continue down this path.

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Congress should focus on policies that encourage research and development of all sources of energy, such as carbon capture and sequestration, energy storage, small modular nuclear reactors, or hydropower – to name a few. We should break down regulatory barriers to innovation and promote competition with the goal of making clean energy more affordable, accessible, and reliable – creating jobs, and growing the economy.

In doing so, America will continue to lead other countries in reducing our impact on our climate – without adding to our nation’s debt and disrupting the lives of American workers and families. Innovation is the cornerstone of America – it’s what we do best.
But more government interference and less freedom for Americans is the wrong policy to get the results we want.

I do want to add that it’s not entirely fair to say that there are no ideas on how to pay for the astronomical cost of the Green New Deal. The concept of “Modern Monetary Theory” has been cited as a solution to all our debt problems...because, so the theory goes, the government can just print more money to pay our bills. Now, I’m skeptical of that claim, but I understand that Chairman Yarmuth made some news on this topic in an interview at the Peterson Foundation Fiscal Summit this morning. I’m hopeful a hearing on this theory is on the horizon.

Thank you again Mr. Chairman, and I yield back.
Chairman YARMUTH. Thank you, Mr. Johnson for your opening statement. And I need to apologize to anyone here who is under the impression that this was about—this hearing was about the Green New Deal. I know the Republicans put out notices that we were going to have a hearing on the Green New Deal. There are 11 Committees that have jurisdiction over that piece of legislation; we are not one of them. As I said, this hearing is about the economic impact of climate change, and I am very, very excited that we have four very, very knowledgeable——

Mr. JOHNSON. Would the Chairman yield?

Chairman YARMUTH. Certainly.

Mr. JOHNSON. Mr. Chairman, how can we have a discussion, a serious discussion about climate change on this Committee, without addressing the primary plank of the platform that you and your colleagues have offered, the Green New Deal, to resolve climate change?

Chairman YARMUTH. Well, as you mentioned, the Green New Deal doesn’t even have a majority of the caucus as cosponsors. But there are hundreds of proposals to deal with climate change, and I think a lot of them are very meritorious and we ought to consider them. We ought to start by agreeing that there is a problem here, and we need to act responsibly, as a Congress, to address it. But now I would like to introduce our witnesses. Once again, each of you will have five minutes to present your testimony. Your written statements have become—been made a part of the record. So, as—I first get to introduce Dr. Hayhoe.

And Dr. Hayhoe, you are recognized for five minutes.

STATEMENT OF KATHARINE HAYHOE, PH.D., PROFESSOR, DEPARTMENT OF POLITICAL SCIENCE, AND DIRECTOR OF THE CLIMATE SCIENCE CENTER, TEXAS TECH; SOLOMON HSING, PH.D., CHANCELLOR’S PROFESSOR OF PUBLIC POLICY, UNIVERSITY OF CALIFORNIA, BERKLEY, AND GLORIA AND RICHARD KUSHEL VISITING SCHOLAR AT STANFORD UNIVERSITY; J. ALFREDO GOMEZ, DIRECTOR, NATURAL RESOURCES AND ENVIRONMENT, U.S. GOVERNMENT ACCOUNTABILITY OFFICE; AND OREN CASS, SENIOR FELLOW, MANHATTAN INSTITUTE

STATEMENT OF KATHARINE HAYHOE, PH.D.

Dr. HAYHOE. Thank you, Chairman Yarmuth, Member Johnson, and Committee Members for inviting me to speak today.

My name is Katharine Hayhoe. I am an atmospheric—or climate—scientist, and a professor at Texas Tech University. My research focuses on understanding what climate change means to us in the places where we live. I also spend a lot of time talking about climate change because, according to the Yale Program on Climate Communication, while 70 percent of us in the U.S. agree climate is changing, and it will harm plants, animals, and future generations, only 41 percent of us believe it will affect us personally.

But that is not true. The message of the fourth National U.S. Climate Assessment, or the NCA, is crystal clear. Climate change is already affecting every region of the U.S., and nearly every sector,
including our ag, infrastructure, water, and more. Climate change is not just an environmental issue; it is a health issue, a resource issue, and, most relevant to this Committee, an economic issue, as well.

So my testimony today highlights the findings of the NCA across the U.S. And, of course, I am speaking on my own behalf, based on my expertise in climate impacts and my role as a lead author of the assessment. This testimony is not a product of the NCA process, the USGCRP, or Texas Tech University.

Before I begin our brief tour on how climate change is already affecting the U.S., I want to unequivocally state that, contrary to what you may have heard, NCA is not based on a so-called “most extreme scenario.” It looks at a range of future scenarios, from higher ones, where we continue to depend on fossil fuels as the world does today, to scenarios so low that we only have a few years left before that ship sails and they are off the table.

Which of these is most likely? Over the last two decades it is clear that the observed increase in global carbon emissions has been consistent with the higher scenarios. Looking to the future, though, the question of which scenario is more likely is not one that the science can answer. Instead, the answer is up to us.

As NCA concludes, climate change beyond the next few decades will depend primarily on the amount of heat trapping or greenhouse gases, especially carbon dioxide, emitted globally. We humans are in the driver’s seat, and we are conducting an unprecedented experiment with the only home we have.

Returning to our main theme, though, it is clear that climate change is no longer an issue that can be put on the back burner for future generations. It is already affecting us right now in the places where we live. And one of the most visible ways it is doing so is by exacerbating many of our naturally-occurring weather and climate risks.

For example, where I live in Texas, hurricanes are nothing new. They are not getting more frequent, but they are intensifying faster on average, and getting stronger, bigger, and slower. It is estimated that between 20 to nearly 40 percent of the rain that fell during Hurricane Harvey, and a significant share of the over $125 billion worth of damage it caused, was because of a warmer climate.

Thanks to sea level rise, sunny-day flooding is already affecting property values in coastal cities like Miami. It is estimated by one study that, by the end of the century, homes and commercial properties across the U.S. worth over $1 trillion could be at risk.

In the northeast and the Midwest, heavy precipitation is increasing. When the fields are too wet, farmers have to delay their planting by weeks, as happened this very year. Flood risk is also increasing. In Iowa, for example, what used to be considered 500-year floods just 30 years ago are now 100-year floods.

Warmer temperatures are also helping invasive species spread northward. In Arkansas, for example, herbicide-resistant Palmer amaranth, known as pigweed, has been called the greatest pest facing cotton and soybean producers today.

In the western U.S. the number of wildfires is not increasing, but they are burning twice the area, thanks to climate change. In addi-
tion to destroying homes and infrastructure, just this past year PG&E, California’s largest utility, sited $30 billion worth of liabilities due to wildfire in their bankruptcy filing.

Many more details are available in my written deposition and, of course, in the NCA itself. But the bottom line is this: We care about a changing climate because it is loading the natural weather dice against us. It is taking many of our naturally-occurring risks, and making them worse in ways that affect us here and now. We are already starting to adapt, but—this is a very important qualifier—we are not adapting fast enough. And the further and faster climate changes, the more difficult and expensive—and, in some cases, ultimately impossible—it may be to do so.

That is why it is so important to prepare, to build resilience to the risks we can’t avoid, and to reduce our emissions of heat-trapping gases to avoid the risks that we can. The NCA sounds the warning, looking ahead down that road to provide the information that we need to make the good decisions that will ensure a safe future for ourselves, our families, our communities, and us all.

Thank you.

[The prepared statement of Katharine Hayhoe follows:]
Statement of Katharine Hayhoe

Professor, Department of Political Science
Co-Director, Climate Science Center
Texas Tech University

To be presented to:
United States House Committee on the Budget
June 11, 2019

Thank you, Chairman Yarmuth, Ranking Member Womack, and committee members for inviting me to speak today.

My name is Katharine Hayhoe. I am an atmospheric, or climate, scientist. I am also a Professor in the Department of Political Science at Texas Tech University in Lubbock, Texas, and a co-director of the Climate Science Center, an interdisciplinary effort that is part of the Department of the Interior’s South-Central Climate Science and Adaptation Center.

At our Centers, we work with stakeholders across Oklahoma, Texas, Louisiana, and New Mexico to quantify the impacts of climate variability and long-term trends on our region and provide the data and the science we need to be good stewards of our land and our resources. My own research focuses on understanding what climate change means to us in the places where we live. I evaluate global climate models at the regional scale, develop and test the methods we use to translate global climate model output into high-resolution projections, and work with federal,
state, and city organizations to incorporate this information into robust planning strategies that build resilience to a changing climate.

I also spend a great deal of my time talking about climate change – because according to the Yale Program on Climate Communication’s public opinion surveys, while 70 percent of us agree that climate is changing and it will harm plants, animals, and future generations, only 41 percent of us believe that it will affect us personally.

Yet after serving a lead author on the Second, Third, and both Volumes 1 and 2 of the most recent Fourth National Climate Assessment over the last decade, I know this is not true. We care about a changing climate because it affects us personally, in the places where we live, in ways that matter to us. It is no longer only about the polar bears or people living on low-lying islands in the South Pacific or future generations. The message of the Fourth National Climate Assessment is crystal clear: climate change is already affecting every region of the U.S. and nearly every sector, including our agriculture, infrastructure, water, and more. Climate change is not just an environmental issue. It’s a health issue, a resource issue, a national security issue, a humanitarian issue – and, most relevant to this committee, an economic issue as well.

My testimony today focuses on highlighting the findings of the Fourth National Climate Assessment for each region of the United States, with the addition of more recent scientific findings and/or events where relevant. In doing so, I am speaking on my own behalf, based on my technical expertise in regional climate impacts. This testimony is not a product of the
National Climate Assessment process, nor does it represent the positions of the U.S. Global Change Research Program or Texas Tech University.

The U.S. Global Change Research Program (USGCRP) was signed into law by President George H. W. Bush under the Global Warming Response Act of 1990. It is tasked with producing a National Climate Assessment every four years, which among other goals is directed to analyze “the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity” and also “current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.”

The Fourth National Climate Assessment fulfills these goals. In nearly 500 pages, Volume 1 – which was released in November 2017 -- clearly documents how climate is changing, humans are responsible, and the impacts both globally as well as for the U.S. become more severe the more heat-trapping or greenhouse gases we emit. In over 1600 pages, Volume 2 – the so-called “Black Friday” report that was released in 2018, the day after Thanksgiving – expands on how climate change is already affecting the United States’ water; energy supply, delivery and demand; land cover and land use; forests; ecosystems, ecosystem services, and biodiversity; coasts; ocean and marine resources; agriculture and rural communities; built environment, urban systems and cities; transportation; air quality; human health; tribes and indigenous peoples; and international interests.
Volume 2 finds that people and organizations across the country are already responding and beginning to adapt to the changes that have already occurred. But — and this is a very important qualifier — it also concludes that we are not adapting fast enough; and the further and faster climate changes as a result of human emissions of heat-trapping gases, the more difficult and expensive and, in some cases, ultimately impossible it may be to adapt to future change.

Before I begin our brief tour of how climate change is already affecting, and is expected to continue to affect, each region of the U.S., I want to specifically discuss how the Fourth National Climate Assessment addressed the two goals above, in order to clarify some statements that have been made that you may have heard reported on in the media.

I am the lead author on Chapter 4 of Volume 1, which addresses future projections, uncertainty, and scenarios. As such, I can unequivocally state that our analysis was not based on a single or even a range of, quote, “most extreme” scenarios. Rather, we examined the impacts of a range of future scenarios, from higher scenarios where we continue to depend on fossil fuels as our primary source of energy, to scenarios that are so low that we only have a matter of years left in the global carbon budget before they are off the table: specifically, one and a half years’ worth of additional carbon emissions at present-day rates for a 50% chance of remaining below 1.5°C, and between 16 to 21 years’ worth of additional carbon emissions to have a 50% chance of remaining below 2°C (Volume 1, Table 14.1). This is a very broad range of possible futures, and this range was carried throughout Volume 2, where the impacts by sector and region were clearly and unmistakably delineated as corresponding to a “higher scenario,” a “lower scenario,” and an “even lower scenario.”
Which of these scenarios is most likely? Looking back over the last two decades, it is clear that “the observed increase in global carbon emissions over the past 15–20 years has been consistent with higher scenarios (very high confidence).” (Volume 1, Chapter 4). Looking to the future, however, the question of which scenario is more likely is not one that science can answer. Instead, the answer is up to us.

Today, “global climate continues to change rapidly compared to the pace of the natural variations in climate that have occurred throughout Earth’s history,” (Volume 1, Chapter 1) and “observational evidence does not support any credible natural explanations for this amount of warming: instead, the evidence consistently points to human activities, especially emissions of greenhouse or heat-trapping gases, as the dominant cause.” (Volume 2, Chapter 2)

“The magnitude of climate change beyond the next few decades will depend primarily on the amount of greenhouse gases (especially carbon dioxide) emitted globally.” (Volume 1, Chapter 1) We are conducting an unprecedented experiment with the only home we have and, as Chapter 4 concludes, “the present-day emissions rate of nearly 10 GtC per year suggests that there is no climate analog for this century any time in at least the last 50 million years,” a time that so far away that, though it sounds astronomical to us, subsequent research has found to be likely even further back than that.

Returning to our main theme: it’s clear that climate change is no longer an issue that can be put on the back burner for future generations to worry about. It’s already affecting us, right now, in
the places where we live. And the more heat-trapping or greenhouse gasses we produce, the more serious the impacts we’ll experience. The future is in our hands.

As climate changes and the planet warms, many of our naturally-occurring risks and our pre-existing vulnerabilities are being exacerbated in ways that affect us directly, here and now. One of the most important ways a changing climate affects us is by loading the natural weather dice against us. Specifically (Volume 2, Chapter 2).

- Heat waves have become more frequent in the United States since the 1960s, while extreme cold has become less frequent.

- Heavy precipitation is increasing in intensity and frequency across the United States and these observed increases are projected to continue in most parts of the U.S., particularly the Northeast and the Midwest.

- Soils are likely to become drier and snowpack in the western states is likely to decrease, increasing the intensity of droughts.

- Hurricanes are not becoming more frequent; but with 93% of the extra heat trapped inside the climate system by our heat-trapping gas emissions going into the ocean where it can power stronger tropical storms, we are seeing (and expect to continue to see) these storms intensifying faster, on average, and becoming on average stronger, bigger, slower, and with more rainfall associated with them.

- Global average sea level has risen by about 7-8 inches since 1900, and it’s accelerating: almost half of this rise has occurred since 1993. The rate at which sea level is rising is now almost three times faster than the average rate over the last century.
Coastal flooding, particularly what they call nuisance or “sunny day” flooding is now more frequent. In some cities, this type of flooding has increased by a factor of five to ten since the 1950s.

Typically, it isn’t a case of climate change creating new risks that have never existed before, but rather a case of climate change interacting with existing risks and exacerbating or amplifying them through exposure, vulnerability, and changes in extreme weather and climate events themselves.

We begin our tour in the Northeast U.S., where winters are milder, spring is coming earlier, and warming temperatures are altering many of the very things that make the region so unique, from its beautiful lakes to iconic crops like blueberries and maple syrup. Tourism is an important economic driver for many small towns: fall colors are multi-billion-dollar tourist attraction across the region, and in Maine alone, snowmobiling brings in well over 200 million dollars a year. But more and more often, the peak leaf season is shifting to earlier in the year, and as the mix of trees changes, the colors may not be as spectacular. And warmer winters mean less snow and ice for skiing, snowmobiling, and ice fishing. The impact of warm winters such as occurred a few years ago can be devastating for the economies of many rural communities. And the region’s coasts support fishing and aquaculture businesses: as sea level rises, the ocean warms, and ocean acidification continues, these are all under threat. The Gulf of Maine is warming faster than most ocean areas and that’s affecting shellfish and the lobster industry. Further north, in Maine, lobster harvests are doing well as the water has warmed to the ideal temperature but south of Cape Cod, these harvests are already collapsing as the water warms above the level
where lobsters can thrive. And then there’s the fact that this region has seen the largest increase in heavy precipitation of any in the U.S. Cities with their paved surfaces are particularly at risk, and the economic impacts have the potential to be significant: since 1980, Northeast states have already experienced anywhere from 7, for Vermont, up to 19, for New York state, extreme precipitation events where damages from flood or snow topped a billion dollars.

The Southeast is next. It’s no stranger to invasive species: it already costs tens (sometimes even hundreds) of millions of dollars to remove kudzu, originally planted by farmers in the first half of the 20th century, from essential infrastructure. Palmer amaranth, known as the “superweed,” is attacking fields in the region including corn, soybeans and cotton. Many people in the Southeast also live along the coastline, both the Atlantic and the Gulf of Mexico. This is one of the key areas where the “sunny day flooding” I mentioned earlier is already a problem, with roads, buildings, and even parking garages flooding even when there’s no storm. This is already affecting property values in coastal cities like Miami where property prices for homes vulnerable to sea level rise have already dropped an average of seven percent relative to neighbors just a few blocks inland. If no action is taken to reduce carbon emissions, it’s estimated that high tide flooding throughout the southern states could be a daily occurrence by the end of the century, putting hundreds of billions of dollars of infrastructure at risk, as well as key and iconic sites from the Florida Keys to the NASA Kennedy Space Center in Cape Canaveral. And of course sea level rise also exacerbates storm surge; and as I discussed above, hurricanes are not any more frequent than they used to be, but they are stronger, with more rainfall associated with them which, if we don’t prepare for these changes, will increase the costs and damages from the storms.
The southern Great Plains, where I live, also lies along the Gulf of Mexico. Because of its geographic location, it is naturally at risk for a greater number of expensive weather and climate disasters, from ice storms to hurricanes, than any other region in the U.S. Since 1980, Texas alone has experienced 105 events that have caused at least a billion dollars’ worth of damage; some events, like Hurricane Harvey, well over one hundred billion dollars. Of course hurricanes in the Gulf are nothing new – the Galveston hurricane of 1900 was devastating. But it’s estimated that between 20 to nearly 40 percent of the rain that fell during Hurricane Harvey was the result of a warmer climate. Heavy rainfall from regular storms is also increasing, particularly across the eastern half of the region, and as temperatures increase, my own research shows that summer droughts, when they come, will be getting stronger and more frequent as well. Natural patterns of feast and famine, flood and drought, are being amplified across much of the region, with potentially devastating consequences for our region’s agriculture, water, and more.

Moving westward to the Southwest U.S., the story there is also about water: how there’s already not enough. The Southwest has always been susceptible to mega-droughts, as far back as tree-ring records go: but as the world warms these naturally-occurring droughts are intensifying, getting hotter and longer. California, for example, has experienced many droughts, but 2011 to 2014 was the driest period for California since record-keeping began. The onset of the drought was consistent with natural patterns of precipitation variability, but record-high temperatures that accompanied the drought enhanced the atmospheric ridge of high pressure that diverted the winter storms away from the region when it needed them most. Over a hundred million trees died, hydroelectric power generation dropped by two-thirds, and the economic impacts averaged
between 2 to 3 billion dollars per year. The drought ended dramatically with the winter of 2016, which was also the wettest on record for Northern California. The rainfall was fueled by atmospheric rivers, which currently account for 30 to 40 percent of annual precipitation along the western US coast. The frequency and severity of these events are projected to increase due to warmer temperatures and more winter precipitation is falling as rain and less as snow. This means less winter snowpack, which serves as a natural reservoir or storage for many states, from Colorado to California.

Moving up to the Pacific Northwest, climate change threatens the diversity and the resources that make this region so unique. Those most at risk are communities that are already economically disadvantaged, or those that are most dependent on natural resources for their livelihoods, including many tribal nations. Since the 1950s, snowpack on April 1st has declined by an average of about 25 percent across the Cascades, with some locations experiencing up to 60 percent decrease. In the future, snowpack is expected to continue to decline, and the risk of wildfire is expected to increase due to warmer temperatures and earlier (and less) spring snowmelt. Across the entire west, the number of wildfires is not increasing, but the cumulative area burned since 1985 is approximately double what it would be in the absence of a changing climate and the season is beginning earlier and ending later. In addition to the destruction of homes and infrastructure, wildfires also affect the region’s agriculture, hydropower, and the quality of the air and the drinking water.

In the northern Great Plains, water is the lifeblood of the region. Even small changes in annual snow and rainfall totals can have significant impacts. As temperatures warm, more precipitation
is likely to fall as rain, and less as snow. Across the entire northern Great Plains region, warming
has already led to shorter snow seasons, lower summer streamflow, and higher water
temperatures. This is affecting the region’s wildlife, and local economies that depend on the
tourism revenue from recreational activities like skiing, snowmobiling, and fishing. The good
news is that agriculture in the northern Great Plains is benefitting from longer growing seasons
and higher CO₂ levels. Farmers in North Dakota can now grow corn and soybeans in areas that
were previously too cold to plant them. While this is increasing livestock production and
extending the growing season for crops, it is also increasing the ability of weeds and invasive
species to compete with crops for nutrients. With greater warming, more negative impacts are
expected, with increasing risk of summer heat waves, extreme precipitation, and the northward
migration of pests and invasive species previously kept at bay by cold winter temperatures.

The story in the Midwest is about agriculture and water too. In this region, not only are
temperatures increasing but winter and spring precipitation increasing as well, as is the frequency
of heavy precipitation. When fields are too wet in the spring, farmers have to delay their planting
by weeks, as happened this very year. Climate change is also increasing flood risk in many areas
throughout the Midwest. In Cedar Rapids and Des Moines, for example, what were considered
500-year floods just 30 years ago are now considered 100-year floods. Across the region, it’s
estimated it will cost nearly half a billion dollars to adapt urban storm water systems to the more
frequent and severe storms expected over this century.

Then there’s Alaska, in many ways the poster child for observing a warmer planet with our own
eyes. Temperatures in Alaska and the Arctic are warming twice as fast, on average, as the rest of
the world. Much of Alaska’s infrastructure, from buildings to roads to oil pipelines, is built on what used to be permanently frozen ground. As this permafrost thaws, infrastructure damages are estimated to range from about one hundred to nearly three hundred million dollars per year. Many remote communities in the far north, often populated by native Americans, are accessed solely by “winter roads” or rail lines. The winter road season is getting shorter, isolating many of these communities. And of course warmer temperatures and retreating sea ice are already impacting traditional Inuit livelihoods and culture, driving rapid changes to unique and fragile ecosystems on land and in the ocean, increasing the risk of wildfire and yes, endangering the polar bear. When it comes to climate change, Alaska truly is on the front lines.

And lastly, we can’t forget the islands: Hawai’i, Puerto Rico, and many more who are uniquely vulnerable due to their limited land area. Many islanders live along the coasts where sea level rise, stronger storm surge, and more powerful tropical cyclones, typhoons, and hurricanes put them directly in harm’s way. The 2017 hurricane season showed how devastating these storms are to the Caribbean. Hurricane Irma decimated St John in the Virgin Islands and destroyed 95 percent of the homes on Barbuda, leaving it uninhabitable for months. Hurricane Maria was the worst disaster in recorded history to hit the islands of Puerto Rico and Dominica. Even without the effect of stronger storms, Hawai’i estimates sea level rise will cost at least 15 billion dollars - over 50 times the entire annual budget of the state’s Department of Transportation—just to raise or relocate basic roadways, bridges, and other infrastructure to preserve them from this slow-motion flooding. Islands are also very sensitive to drought. In both the Caribbean and the Pacific, freshwater resources are expected to decline over time as average rainfall decreases and rising sea level increases contamination of freshwater coastal aquifers due to saltwater intrusion. And
Finally, tourism and the fishing industry depend on the resources available off the coast. In Hawaii alone, it’s estimated that coral reefs contribute nearly half a billion dollars to the local economy each year. Warming ocean waters, increasing acidification, and the added risk of de-oxygen-ization all exacerbate existing problems of pollution, runoff, and unsustainable harvesting of resources, putting the regions’ economies and livelihoods at risk.

We care about a changing climate because it’s loading the dice against us. It’s taking many of our naturally-occurring risks and our pre-existing vulnerabilities, and it’s making them worse -- in ways that affect us directly, here and now.

I live in West Texas, where the roads are long and straight. So straight that, in some places, you could drive down the highway just looking in the rearview mirror. Until, that is, you hit a curve. And then, if you’re looking backwards, you’ll end up somewhere you didn’t plan to be.

What does this have to do with climate? The same principle applies: the information we use to plan for our future is crucial. If we’re relying on historical climate averages to determine future risks, we’ll end up far from where we wanted to be, unprepared for the intense flooding, record heat waves, or rising seas up ahead.

No matter where we live, we’re on the curve today. And that’s why it’s so important to prepare: to build resilience to the risks we can’t avoid, and to reduce our emissions of heat-trapping gases, to avoid the risks we can. The more carbon we produce, the more serious the impacts -- not just for polar bears or future generations, but for us as well. We’re all on the bus, heading around the
curve, and our wheels are on the rumble strip. The National Climate Assessment sounds the warning and provides the information we need to ensure that we all navigate that curve safely and provide the safe future we all want, regardless of our political affiliation or our priorities—because it’s for ourselves, our communities, and most of all, our children. For me as a mother, there’s no more powerful motivation than that.
Chairman YARMUTH. Thank you for your testimony. I now yield five minutes to Dr. Hsiang.

STATEMENT OF SOLOMON HSIANG, PH.D.

Dr. HSIANG. Thank you, Chairman Yarmouth, Ranking Member Womack, and Members of the Committee for inviting me to speak today.

My name is Solomon Hsiang, and I am the chancellor's professor of public policy at the University of California Berkeley, and currently a visiting scholar at Stanford. I was trained in both economics and climate physics at Columbia, MIT, and Princeton. My research focuses on the use of econometrics to measure the effect of the climate on the economy.

The last decade has seen dramatic advances in our understanding of the economic value of the climate. Crucially, we are now able to use real-world data to quantify how changes in the climate cause changes in the economy. This means that, in addition to being able to project how unmitigated emission of greenhouse gases will cause the physical climate to change, we now also can estimate the subsequent effect that these changes are likely to have on the livelihoods of Americans.

Although, as with any emerging research field, there are large uncertainties, and much work remains to be done. Nonetheless, I would like to describe to you seven key insights from this field regarding future risks if past emission trends continue unabated.

First, climate change is likely to have substantial negative impact on the U.S. economy. Expected damages are on the scale of trillions of dollars, although there remains uncertainty in these numbers. For an example, in a detailed analysis of county-level productivity, a colleague at University of Illinois and I estimated that the direct thermal effects alone would likely reduce incomes nationwide over the next 80 years, a loss valued at roughly $5 to $10 trillion in net present value. In another analysis a colleague from the University of Chicago and I computed that losses from intensified hurricanes were valued at around $900 billion. Importantly, these numbers are not a complete accounting of impacts, and other notable studies report larger losses.

Second, extreme weather events are short-lived, but their economic impact is long-lasting. Hurricanes, floods, droughts, and fires destroy assets that took communities years to build. Rebuilding then diverts resources away from new, productive investments that would have otherwise supported future growth. For example, a colleague at Rhodium Group and I estimated that Hurricane Maria set Puerto Rico back over two decades of progress, and research done at MIT indicates that communities in the Great Plains have still not fully recovered from the Dustbowl of the 1930s. As climate change makes extreme events more intense and frequent, we will spend more attention and more money replacing depreciated assets and repairing communities.

Third, the nature and magnitude of projected costs differs between locations and industries. For example, extreme heat will impose large health, energy, and labor costs on the south; sea level rise and hurricanes will damage the Gulf Coast; and declining crop yields will transform the Plains and Midwest.
Fourth, because low-income regions and individuals tend to be hurt more, climate change will widen existing economic inequality. For example, in a national analysis of many sectors, the poorest counties suffered median losses that were nine times larger than the richest.

Fifth, many impacts of climate change will not be felt in the marketplace, but rather in homes where health, happiness, and freedom through violence will be affected. There are many examples of this. Mortality due to extreme heat is projected to rise dramatically. Increasingly, humid summers are projected to degrade happiness and sleep quality. Research from Harvard indicates that warming will likely elevate violent crime nationwide, producing over 180,000 sexual assaults and over 22,000 murders across eight decades. Colleagues at Stanford and I estimate that warming will generate roughly 14,000 additional suicides in the next 30 years. Increasing exposure of pregnant mothers to extreme heat and cyclones will harm fetuses for their lifetime. These impacts do not easily convert to dollars and cents, but they merit attention.

Sixth, populations across the country will try to adapt to climate at substantial cost. Some adaptations will transform jobs and lifestyles. Some will require constructing new defensive infrastructure, and some will involve abandoning communities and industries where opportunities have deteriorated. In all cases, these adaptations will come at real cost, since resources expended on coping cannot be invested elsewhere.

Lastly, outside of the U.S., the global consequences of climate change are projected to be large and destabilizing. Unmitigated warming will likely slow global growth roughly a third of a percentage point, and reduce political stability throughout the tropics and subtropics.

Together, these findings indicate that our climate is one of the nation’s most important economic assets. We should manage it with the seriousness and clarity of thought that we would apply to managing any other asset that also generates trillions of dollars in value for the American people.

Thank you.

[The prepared statement of Solomon Hsiang follows:]
Statement of Solomon Hsiang  
Chancellor’s Professor of Public Policy, University of California, Berkeley  
Director, Global Policy Laboratory, Goldman School of Public Policy  
Co-Director, The Climate Impact Lab  

To be presented to:  
United States House Committee on the Budget, hearing on  
“The Costs of Climate Change: Risks to the U.S. Economy and the Federal Budget”  

June 10, 2019  

Thank you Chairman Yarmuth, Ranking Member Womack, and members of the Committee for inviting me to speak today.  

My name is Solomon Hsiang, and I am the Chancellor’s Professor of Public Policy at the University of California, Berkeley and currently the Kushel Visiting Scholar at Stanford University. I was trained in both economics and climate physics at Columbia, MIT, and Princeton. My research focuses on the use of econometrics to measure the effect of the climate on the economy and I co-direct the Climate Impact Lab, a multi-institution effort to systematically quantify the economic costs of climate change. I am here in my personal capacity to describe what I believe are the most important findings in this emerging field of research.  

When approaching climate change as an economic problem, we do not think about the climate aesthetically. Instead, we think of the climate as a capital asset that generates economic value just like any other human-made capital asset, even though we do not own or have complete control over it. The climate generates value by improving the function and performance of all other components of our economy, in some ways similar to how the internet or the national highway system generate value for our economy. Because we now understand that human actions are affecting the climate of the United States, it is in the nation’s best economic interest that we consider whether our actions increase or decrease the value of this national asset.  

Hundreds of researchers around the world are now using massive data repositories to understand the effects of the climate, and the potential impacts of climate change, on modern society. The last decade has seen dramatic advances in our understanding of the economic value of the climate, driven by unprecedented access to data, computing, and methodological advances. An important advance has been developing the ability to use real-world data to quantify how changes in the climate cause changes in the economy. This means that in addition to being able to project how unmitigated emission of greenhouse gases will cause the physical climate to change, we are now developing the ability to also estimate the subsequent effect that these changes are likely to have on the livelihoods of Americans.¹  

Modern researchers use careful analysis of detailed data to understand how different elements of the economy respond to changes in different components of the climate. For example, an econometrician might examine how crop yields, crop acreages, worker wages, and farm profits  

change as counties in Nebraska get warmer or cooler over time. These results are then used to consider how these economic variables might change next year given the amount of climate change that is forecast for next year. Extending the procedure year-after-year allows us to consider economic effects over longer time-horizons, although with increasing uncertainty. The analyses I describe represent the best available current science, employing data and methods developed and published in the world’s top peer-reviewed scientific and economic research journals, but there nonetheless invariably remains substantial uncertainty in many results from this emerging field. Researchers generally spend tremendous effort meticulously tracking and reporting sources of uncertainty in their analyses, which I will try to represent and interpret.

Because there are numerous irreducible uncertainties about the future of the global economy, such as the unknowable path of future technological innovation, research on the economic effects of future climate change explicitly does not attempt to forecast the future. Rather, researchers use a risk-management framework in which they try to determine the direction and strength with which climate changes will nudge society, relative to some baseline trajectory with “no climate change”, and then assign probabilities to different possible outcomes. This information can then be used to value the potential risks or rewards of pursuing different climate objectives, relative to the baseline. Because both the baseline economic pathway and any climate change-affected pathway both contain the same fundamental uncertainties about the future, these uncertainties do not affect the difference in economic outcomes between these two pathways, which is the object of interest from a risk-management standpoint. Thus, research findings in this field should be interpreted similarly to medical recommendations regarding current behaviors that affect future health: the future cannot be known, but certain actions today can be determined to systematically increase or decrease risk of a particular outcome of interest in the future.

In what follows, unless otherwise specified, I will refer to the Representative Concentration Pathway (RCP) 8.5 specified by the Climate Model Intercomparing Project as “unmitigated climate change,” since it is the path emissions would be expected to take if past trends continue unabated. In general, this trajectory is usually compared to a baseline resembling the climate of the late twentieth century.

The following are key insights from this emerging field that I believe merit your attention.

1. Unmitigated climate change is likely to have substantial net negative impact on the US economy overall.

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2. Extreme weather events are short-lived, but their economic impact is long-lasting.

3. The nature and magnitude of projected costs differs between locations and industries.

4. Because lower income regions and individuals tend to be more adversely impacted, climate change will likely widen existing economic inequality.

5. Many impacts of climate change will not be felt in the marketplace, but rather in homes where health, happiness, and freedom from violence will be affected.

6. Populations across the country will try to adapt to climate change at substantial cost, with varying degrees of success.

7. Outside of the US, the global consequences of climate change are projected to be large and destabilizing.

8. Uncertainty about the consequences of climate change itself represents a separate type of economic harm, because it is costly to cope with.

I discuss these points below.

1. **Unmitigated climate change is likely to have substantial negative impact on the US economy.**

There are two general approaches used to understand how the economic consequences of climate change add up, often referred to as “bottom up” and “top down” approaches. The bottom up approach enumerates many effects that can each be observed, such as crop losses and health impacts, and then integrates them to develop an overall picture of net economic consequences. The top down approach views the economy as a whole, bundling together those aspects of the economy that are captured in regional and national accounting statistics, and tries to understand how these aggregate measures will respond to climate change.

A benefit of the bottom up approach is that it can capture many “non-market” impacts of climate change that may be important, such as changes to human health, but which are not normally priced into aggregate economic measures. The core drawback of the bottom up approach is that it is difficult to develop a complete picture of impacts, since enumerating each impact individually and then integrating these estimates together is data and labor intensive. As an example, in one effort to integrate findings from across the literature, colleagues from several institutions, including Rutgers University, University of Chicago, Columbia University, Princeton University, and the Rhodium Group, computed some combined effects of climate change on agriculture, energy, labor, health, crime, and coastal communities. This analysis estimated that economic damage from warming was quadratic in global mean temperature, but each 1°C increase cost the US roughly 1.2% of GDP in aggregate—although this analysis omitted many known impacts,

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did not model future unprecedented adaptations, and assumed the structure of the economy remained fixed. This analysis also did not compute the stream of damages and thus did not report a net present value for these costs. Continued work with my colleagues at the Climate Impact Lab is improving upon this original work and addressing these issues. In a different recent effort, using a different modeling approach, researchers at the Environmental Protection Agency analyzed 22 sectors at high spatial resolution and found that all regions of the country suffered substantial costs from unmitigated climate change, but they also did not report net present value estimates of total projected losses.

A benefit of the alternative top-down approach is that it captures many elements of the market economy more completely than the bottom-up approach, since it captures all elements of the economy described by national accounting statistics. Another benefit is that, under certain conditions and methods of implementation, it can be understood to broadly capture the costs and benefits of adaptation to climate change. A drawback is that this approach may miss many impacts that are important but are not counted in national accounts, like human health. As an example, in a detailed analysis of county-level productivity data, Tatyana Deryugina at the University of Illinois, Urbana-Champaign and I estimate that the direct thermal effects of warming would reduce incomes nationwide over the next 80 years, a loss valued at roughly $4.7–10.4 trillion (90% confidence interval) in net present value using a 3% discount rate. Similar findings have since been replicated by researchers at the Federal Reserve Bank of Richmond, the Inter-American Development Bank, and University of North Carolina using state-level data and researchers at Stanford University using MSA-level data. In another example, Amir Jina at the University of Chicago and I compute that foregone earnings, due to intensified hurricanes that lower economic growth, are valued at roughly $0.4–1.3 trillion (95% confidence interval) in net present value using a 5% discount rate. Similar findings have since been replicated by researchers at Brown University and University of Arizona, as well as by researcher at the International Monetary Fund.

Importantly, all of these estimates are known to not be a complete accounting of impacts and should be interpreted with caution. In particular, impacts after 2100 are generally omitted entirely. Nonetheless, these estimates provide a sense of scale and scope for the likely potential impact that climate change might be expected to have on the US economy.

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2. Extreme weather events are short-lived, but their economic impact is long-lasting.

Hurricanes, floods, tornados, droughts, and fires destroy assets that took communities years to build. Efforts to rebuild then diverts resources away from new productive investments that would have otherwise supported future economic growth. For example, Trevor Houser at the Rhodium Group, Amir Jina at the University of Chicago, and I estimated that Hurricane Maria set Puerto Rico back over two decades of progress; and research by Richard Hornbeck at the University of Chicago indicates that communities in the Great Plains have still not fully recovered from the Dustbowl of the 1930s. Climate change is likely to make many types of extreme events more intense and/or more frequent, forcing us to spend a larger fraction of our attention and revenues on rebuilding depreciated assets and repairing communities. In addition, general equilibrium simulations suggest that accelerating depreciation rates in one region would necessarily raise capital costs for all industries and consumers across the nation, thereby further slowing growth and magnifying the economic impact of extreme events.

3. The nature and magnitude of projected costs differs between locations and industries.

Early economic models of climate change could not resolve impacts at scales finer than the country, but recent research using spatially granular data has revealed that impacts differ dramatically by location. This occurs for a variety of reasons. First, the physical changes projected for different locations may differ, even within a single scenario. Second, the mix of industries that are present differs across locations, and each industry exhibits different responses to climate change. Third, different populations may respond differently to same climatic stress when participating in the same industry because they have different abilities to cope with these stresses, perhaps because they have differential access to resources or technologies. Fourth, many impacts of climate change are nonlinear, so the baseline climate of a location strongly influences the impact of changing that climate. This results in a diversity of projected costs that are highly specific to locations and industries, and it suggests that focusing too heavily on nationally aggregated total costs will miss much of what we think are important consequences of change.

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warming. For example, extreme heat will impose large health, energy, and labor costs on the South; sea level rise and hurricanes will damage coastal communities, particularly Florida; humidity levels similar to those of modern Louisiana will force a restructuring of infrastructure in New England; declining crop productivities will transform land markets throughout the Plains and Midwest; and more frequent fires and water shortages will harm the West.⁹

4. Because low income regions and individuals tend to be more adversely impacted, climate change will widen existing economic inequality.

Research indicates that low income individuals tend to bear greater cost than wealthier individuals when both are subject to the same climatic stress.⁹ In addition, many locations that are poorer today are projected to experience greater economic harms. For example, rural counties are projected to generally suffer larger losses than urban counties because agricultural industries are highly sensitive to climate;²¹ and many locations that are projected to suffer relatively more from extreme heat and coastal impacts tend to have lower income today. For example, in a national analysis of many sectors, the poorest decile of counties suffered median losses that were 9.5 times larger than the richest decile of counties, when losses are measured as a percentage of baseline income.²²

5. Many impacts of climate change will not be felt in the marketplace, but rather in homes where health, happiness, and freedom from violence will be affected.

Market-based measures do not fully capture many elements of wellbeing, economic opportunity, and quality of life that are projected to be affected by climate change. There are many important examples of this from recent research. Mortality rates in hot regions are projected to rise, by over 20 deaths per 100,000 per year (central estimate) in states like Texas and Oklahoma, due to extreme heat and vector-borne diseases.²³ Growing numbers of hot summer days are projected to degrade population-level measures of sleep quality²⁴ and happiness—for example, one detailed analysis of social media behavior indicates that unmitigated warming could lower happiness in the Great Lakes Region by roughly the same amount as would be predicted by turning half of

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Sundays into work days (i.e. Mondays) each year. Such changes in mental wellbeing matter themselves and also have acute impacts. An analysis of FBI crime data projects warming to elevate violent crime across the country, producing an additional 100,000-260,000 sexual assaults and 12,000-33,000 murders (95% confidence intervals) over the next eighty years. In an analysis of CDC data, Marshall Burke at Stanford University, along with colleagues and myself, estimate that unmitigated warming would be very likely to generate between 5,600-26,000 additional suicides (95% confidence interval) over the next thirty years, across the country. Analyses of Census data indicate that increasing exposure of pregnant mothers to extreme heat or hurricane harms fetuses for their lifetimes such that, at age thirty, the child performs measurably worse in the labor market. Many of these impacts of climate change do not easily convert to dollars and cents, but they nonetheless merit consideration in any discussion of climate change costs.

6. Populations across the country will try to adapt to climate change at substantial cost, with varying degrees of success.

It has long been understood that many populations and communities will try to adapt to climate changes, although the overall effectiveness of this adaptation, in terms of costs and benefits, is unclear and remains an area of active research. Households may transform how or where they live, for example, by switching jobs to a new industry or permanently moving their family to less affected areas, as has been observed during recent Corn Belt droughts and following Hurricane Katrina. These adjustments will have benefits and costs to the adapting household, and they may also generate smaller but widespread costs for other households that are not adapting (externalities). For example, industry-switching and migration may induce crowding in the receiving industries or locations, lowering wages and raising home prices, respectively, for individuals already in those industries or locations.

An alternative approach to adapting will involve households and communities making costly defensive investments, such as building sea walls to protect coastal cities,\textsuperscript{33} expanding use of irrigation in agriculture,\textsuperscript{34} purchasing more weather-related insurance for all industries and homes,\textsuperscript{35} fortifying flood-exposed infrastructure,\textsuperscript{36} and building more power plants to support expanded air conditioning usage.\textsuperscript{37} Given currently available technology, we should expect that many of these defensive investments will partially protect families, communities, and industries from some aspects of climate change. We should also expect that deployment, operation, and maintenance of these defensive investments will come at a cost, since resources allocated towards these adaptations would, in the absence of climate change, have otherwise been invested in productive activities or consumed to improve standards of living. In many cases, these costs will likely generate “adaptation gaps” where best-available technologies are not actually adopted by many populations.\textsuperscript{38} It is crucial when considering adaptation to climate change that both the benefits and costs of adaptation are accounted for on equal footing. Presenting only one or the other will produce a one-sided, and fundamentally inaccurate, accounting of the economic costs of climate change.

It is sometimes hypothesized that technological innovation will substantially aid our ability to adapt in the future, by either expanding the range of potential coping strategies or lowering the cost of existing strategies.\textsuperscript{39} While this is almost guaranteed to occur in at least some contexts, it is unknowable how widespread this phenomenon is likely to be. Thus, relying heavily on unknown future innovation would be a form of gambling, from an economic standpoint, since risks cannot be calculated. However, ignoring the potential for future innovation is also unwarranted. For perspective, note that some historical innovations have substantially altered climate impacts in meaningful ways, while others, long-promised, never materialized. For example, widespread adoption of air-conditioning in the 1960’s and 70’s substantially reduced heat-related mortality\textsuperscript{40}, although heat-related productivity losses have persisted.\textsuperscript{41} Meanwhile,

\begin{flushleft}
\textsuperscript{33} Neumann, James et al. "The economics of adaptation along developed coastlines" WIREs Climate Change (2010); Diaz, Delavane B. "Estimating global damages from sea level rise with the Coastal Impact and Adaptation Model (CIAM)." Climatic change 137.1-2 (2016): 143-166.
\textsuperscript{35} Congressional Budget Office, "Expected Costs of Damage From Hurricane Winds and Storm-Related Flooding, June, 2016.
\textsuperscript{37} Aufhammer, Maximilian, Patrick Baylis, and Catherine H. Hausman. "Climate change is projected to have severe impacts on the frequency and intensity of peak electricity demand across the United States." Proceedings of the National Academy of Sciences 114.6 (2017): 1886-1891.
\end{flushleft}
high-yielding heat-tolerant crop varieties have remained elusive, despite decades of optimism and effort by breeders. Some innovations will likely enable adaptations that help some individuals while harming others, for example further automation of manufacturing may make industry more heat resilient, but may reduce employment. Additionally, it should be noted that, similar to all other forms of adaptation, technological innovations also come at a cost (research and development), but unlike other forms of adaptation, these costs are paid by society up front regardless of whether or not efforts to innovate are successful.

7. Outside of the US, the global consequences of climate change are projected to be large and destabilizing.

In addition to substantially altering the structure and productivity of the US economy, research indicates that unmitigated climate change will likely have remarkable international consequences. Similar to the US, economic productivity around the world tends to decline with rising temperatures, rainfall shortages, and more frequent tropical cyclones. For example, Marshall Burke at Stanford University, Edward Miguel at University of California, Berkeley, and I estimated that the thermal effects of unmitigated warming could be expected to substantially slow global economic growth, by roughly 0.28 percentage points (central estimate), on average, throughout the next eighty years—although there is a large degree of uncertainty in these estimates. Food security and social and political stability throughout the tropics and sub tropics are also projected to decline substantially. These effects are likely to be felt in the US through their impact on financial markets, continuous adjustments in the global economy, and growing food prices.

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trading system,50 and increased migration pressure from both economic migrants51 and asylum seekers escaping political violence.52

8. Uncertainty about the consequences of climate change itself represents a separate type of economic harm, because it is costly to cope with.

Uncertainty about the potential magnitude and impact of climate change is sometimes referenced as a reason to slow policies that mitigate greenhouse gas emissions, but this “wait and see” strategy is difficult to justify with economic reasoning. Without question, there remains significant uncertainty about the magnitude of warming and its consequences, with roughly half of this uncertainty coming from indecision among policy-makers regarding emissions policies.53 Economic theory is quite clear that this substantial uncertainty should amplify, rather than diminish, our valuation of the potential future impacts I have described.54 Similar to how volatile stocks are less valuable to investors than predictable ones, a future made more uncertain due to warming is less valuable to us, relative to a more predictable alternative.

It is also important to note that there are many dimensions of climate change that still have unknown economic consequences. For example, scientific research indicates that unmitigated emissions will transform natural ecosystems, make the oceans more acidic, and cause substantial permafrost melt. While many of these physical and ecological changes are understood, their effect on human wellbeing and economic opportunity has not been well measured. These are critical areas of ongoing research.

Finally, many economists have considered how we should price potential “tipping points” in which irreversible regime shifts in the global climate cause extreme and unprecedented economic damage, such as abrupt sea level rise.55 This line of research is more theoretical in nature, since there are no relevant modern example events for economists to study. In general, the possibility that such tipping points might have greater likelihood due to rising greenhouse gas emissions means that a rational, risk-averse economic decision-maker should invest greater resources in

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mitigating those emissions, since there is are not other means to insure or otherwise hedge against such events. Such extreme scenarios may not be visible in recent history nor necessarily likely in the future, but they should nonetheless be carefully considered. Simple dismissal of this concern should be tempered by the numerous historical examples of civilizations with unprecedented technological prowess collapsing under climatic stresses far gentler than what is projected in the next two centuries.

Conclusions

Newly available data and computing empower us have a scientifically-informed dialogue about the ways our actions today will shape the economic environment in which centuries of our descendants will earn their living and raise their families. To my knowledge, this is the first time in human history that such conversations have taken place.

Global efforts in an emerging research field are working vigorously to understand the economic and social consequences of climate change. Insights from this research reveal that the potential costs to the US economy are complex, diverse, and sizable, but this economic future is not locked in. All of the potential risks I have identified here are substantially mitigated by reducing greenhouse gas emissions both in the US and around the world.

The available evidence indicate that our climate may be one of the nation’s most important economic assets. I believe it is in our nation’s best interest to manage it with the seriousness and clarity of thought that we would apply to managing any other asset that also generates trillions of dollars in value for the American people.


Chairman YARMUTH. Thank you for your testimony. I now recognize Mr. Gómez for five minutes.

STATEMENT OF J. ALFREDO GÓMEZ

Mr. Gómez. Chairman Yarmouth, Mr. Johnson, and Members of the Committee, good morning, and I am pleased to be here today to discuss our work on how to limit the federal government’s fiscal exposure by better managing climate change risks.

This is an area that has been on our high-risk list since February 2013. The cost to recent weather disasters have shown us the need for planning for climate change risks and for investing in resilience. My statement today discusses several areas where the federal government faces fiscal exposure from climate change risks, the potential impacts on the federal budget, and how the federal government could reduce this exposure.

So early this year we reported that the federal government faces fiscal exposure from climate change risks in several areas, including disaster aid; federal insurance programs; and federal property and land. The rising number of natural disasters and related federal assistance are a key source of federal fiscal exposure, and this exposure will likely continue to rise.

Since 2005, federal funding for disaster assistance is at least $450 billion. According to the U.S. Global Change Research Program, disaster costs are projected to increase as certain extreme weather events become more frequent and intense due to climate change.

In addition, the National Flood Insurance Program and the Federal Crop Insurance Program are sources of federal fiscal exposure, due in part to the vulnerability of the insured property and crops to climate change.

From 2013 to 2017, losses under these programs totaled $51.3 billion. The federal flood and crop insurance programs were not designed to generate sufficient funds to fully cover all losses and expenses, and need budget authority from Congress to operate.

With regard to federal property, the federal government owns and operates hundreds of thousands of facilities, and manages millions of acres of land that could be affected by a changing climate, and represent a significant federal fiscal exposure. For example, the Department of Defense owns and operates domestic and overseas infrastructure, with an estimated replacement value of about one trillion.

In September 2018 Hurricane Florence damaged Camp LeJeune and other Marine Corps facilities in North Carolina, resulting in a preliminary repair estimate of $3.6 billion. One month later, Hurricane Michael devastated Tyndall Air Force Base in Florida, resulting in preliminary repair estimates of $3 billion.

So, while the federal government faces fiscal exposure from climate change, it does not have certain information that is needed to understand the budgetary impacts of such exposure. For example, the federal budget does not account for disaster assistance provided by Congress or the long-term impacts of climate change on existing federal infrastructure and programs. Also, the Office of Management and Budget climate change funding reports do not include information on federal programs with significant fiscal expo-
sure to climate change. A more complete understanding could help policymakers anticipate changes in future spending, and enhance control and oversight over federal resources.

One way to reduce federal fiscal exposure is to reduce or eliminate long-term risks to people and property from natural hazards. For example, in September 2018 we reported that elevating homes and strengthening building codes prevented greater damages in Texas and Florida during the 2017 hurricane season. The federal government has made some limited investments in resilience. Also, Congress passed the Disaster Recovery Reform Act of 2018, which could enable additional improvements at the state and local level.

However, the federal government lacks a strategic approach for identifying, prioritizing, and implementing investments for disaster resilience.

In summary, the federal government could reduce its fiscal exposure to climate change by focusing and coordinating federal efforts. So we have made a total of 62 recommendations. As of December of last year 25 of these recommendations remain open. Some of these identified key government-wide efforts that are needed to help plan for and manage climate risks, and direct federal efforts toward common goals, such as improving resilience.

For example, to make buildings and infrastructure more resilient, we recommended that the Department of Commerce convene federal agencies to provide standard-setting organizations with the best available forward-looking climate information to inform design standards and building codes.

Chairman Yarmuth, Ranking Members, and Members of the Committee, thank you, that completes my statement.

[The prepared statement of J. Alfredo Gómez follows:]
Testimony
Before the Committee on the Budget,
House of Representatives

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CLIMATE CHANGE
Opportunities to Reduce Federal Fiscal Exposure

Statement of J. Alfredo Gómez, Director, Natural Resources and Environment
CLIMATE CHANGE
Opportunities to Reduce Federal Fiscal Exposure

What GAO Found
The estimated economic effects of climate change, while imprecise, can convey useful insight about potential damages in the United States. In September 2017, GAO reported that the potential economic effects of climate change could be significant and unevenly distributed across sectors and regions (see figure). This is consistent with the recent findings of the U.S. Global Change Research Program’s Fourth National Climate Assessment, which concluded, among other things, that the continued increase in the frequency and extent of high-tide flooding due to sea level rise threatens America’s trillion-dollar coastal infrastructure.

Examples of Potential Economic Effects from Climate Change by 2100

- Decreased agricultural yields
- Increased road damage
- Decreased household income

Information about the potential economic effects of climate change could inform decision makers about significant potential damages in different U.S. sectors or regions. According to prior GAO work, this information could help decision makers identify significant climate risks as an initial step toward managing them. The federal government faces fiscal exposure from climate change risks in several areas, including:

- Disaster aid: due to the rising number of natural disasters and increasing reliance on federal assistance. GAO has previously reported that the federal government does not adequately plan for disaster resilience. GAO has also reported that, due to an artificially low indicator for determining a jurisdiction’s ability to respond to disasters that was set in 1986, the Federal Emergency Management

View GAO-19-629T. For more information, contact J. Alfredo Gómez at (202) 512-3061 or gomezj@gao.gov.

United States Government Accountability Office
Management Agency risks recommending federal assistance for jurisdictions that could recover on their own.

- Federal insurance for property and crops: due, in part, to the vulnerability of insured property and crops to climate change impacts. Federal flood and crop insurance programs were not designed to generate sufficient revenue to fully cover all losses and expenses. The flood insurance program, for example, was about $21 billion in debt to the Treasury as of April 2016. Further, the Congressional Budget Office estimated in May 2019 that federal crop insurance would cost the federal government an average of about $8 billion annually from 2019 through 2029.

- Operation and management of federal property and lands: due to the hundreds of thousands of federal facilities and millions of acres of land that could be affected by a changing climate and more frequent extreme events. For example, in 2018, Hurricane Michael devastated Tyndall Air Force Base in Florida, with a preliminary repair estimate of $3 billion. The federal budget, however, does not generally account for disaster assistance provided by Congress or the long-term impacts of climate change on existing federal infrastructure and programs. GAO has reported that more complete information about fiscal exposure could help policymakers better understand the trade-offs when making spending decisions.

Further, federal investments in resilience to reduce fiscal exposures have been limited. As GAO has reported, enhancing resilience can reduce fiscal exposure by reducing or eliminating long-term risk to people and property from natural hazards. For example, a 2018 interim report by the National Institute of Building Sciences estimated approximate benefits to society in excess of costs for several types of resilience projects. While precise benefits are uncertain, the report estimated that for every dollar invested in designing new buildings to particular design standards, society could accrue benefits amounting to about $11 on average.

The federal government has invested in individual agency efforts that could help build resilience within existing programs or projects. For example, the National Climate Assessment reported that the U.S. military integrates climate risks into its analysis, plans, and programs. In addition, as GAO reported in March 2019, the Disaster Recovery Reform Act of 2018 could improve resilience by allowing the President to set aside a portion of certain grants for pre-disaster mitigation. However, the federal government has not undertaken strategic government-wide planning to manage climate risks.

GAO’s March 2019 High-Risk report identified a number of recommendations GAO has made related to fiscal exposure to climate change. The federal government could reduce its fiscal exposure by implementing these recommendations. Among GAO’s key government-wide recommendations are:

- Entities within the Executive Office of the President (EOP) should work with partners to establish federal strategic climate change priorities that reflect the full range of climate-related federal activities;

- Entities within EOP should use information on potential economic effects from climate change to help identify significant climate risks and craft appropriate federal responses;

- Entities within EOP should designate a federal entity to develop and update a set of authoritative climate observations and projections for use in federal decision making, and create a national climate information system with defined roles for federal agencies and certain nonfederal entities; and

The Department of Commerce should convene federal agencies to provide the best-available forward-looking climate information to organizations that develop design standards and building codes to enhance infrastructure resilience.
Chairman Yarmuth, Ranking Member Womack, and Members of the Committee:

Thank you for the opportunity to discuss our work on how to limit the federal government’s fiscal exposure by better managing climate change risks, an area that has been on our High-Risk List since February 2013.1 Addressing climate change risks requires advanced planning and investment to reduce the need for far more costly steps in the decades to come, which, as we have previously reported, the federal government is not well organized to do. The costs associated with recent disasters have illustrated the need for such planning and investment. In 2018 alone, there were 14 separate billion-dollar weather and climate disaster events across the United States, with a total cost of at least $91 billion, according to the National Oceanic and Atmospheric Administration (NOAA).2 Further, on June 6, 2019, a supplemental appropriation of approximately $19.1 billion was signed into law for recent disasters.

The U.S. Global Change Research Program (USGCRP), which coordinates and integrates the activities of 13 federal agencies that research changes in the global environment and their implications for society, reported in its November 2018 Fourth National Climate Assessment that climate change is playing a role in the increasing frequency of some types of extreme weather that lead to the billion-dollar disasters.3 These changes include the rise in vulnerability to drought, lengthening wildfire seasons, and the potential for extremely heavy rainfall becoming more common in some regions. USGCRP reported in the prior assessment that the costs of many of these disasters will likely

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1Our High-Risk List identifies federal program areas that are at high risk of vulnerabilities to fraud, waste, abuse, and mismanagement or most in need of transformation. See GAO, High-Risk Series: An Update, GAO-12-253 (Washington, D.C.: Feb. 14, 2013).


increase as extreme weather events become more frequent and intense with climate change.\textsuperscript{4}

In my testimony today, I will discuss (1) what is known about the potential economic effects of climate change in the United States and the extent to which this information could help federal decision makers manage climate risks across the federal government, (2) the potential impacts of climate change on the federal budget, (3) the extent to which the federal government has invested in resilience to climate change impacts,\textsuperscript{5} and (4) how the federal government could reduce fiscal exposure to the effects of climate change. My testimony is based on reports we issued from October 2009 to March 2019. More detailed information on our objectives, scope, and methodology can be found in those reports.

The work upon which this statement is based was conducted in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.


\textsuperscript{5}The National Academies of Sciences, Engineering, and Medicine (National Academies) define resilience as the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events. See the National Academies, Committee on Increasing National Resilience to Hazards and Disasters, Committee on Science, Engineering, and Public Policy, Disaster Resilience: A National Imperative (Washington, D.C.: 2012). We reported in May 2016 that two related sets of actions can enhance resilience by reducing risk. These include climate change adaptation and pre-disaster hazard mitigation. Adaptation is defined as adjustments to natural or human systems in response to actual or expected climate change. Pre-disaster hazard mitigation refers to actions taken to reduce the loss of life and property by lessening the impacts of adverse events and applies to all hazards, including terrorism and natural hazards, such as health pandemics or weather-related disasters. In this testimony, we use the term “resilience” for consistency and to encompass both of these sets of actions as they relate to addressing climate risks. GAO, Climate Change: Selected Governments Have Approached Adaptation through Laws and Long-Term Plans. GAO-16-454 (Washington, D.C.: May 12, 2016).
We reported in September 2017 that, while estimates of the economic effects of climate change are imprecise due to modeling and information limitations, they can convey useful insight into broad themes about potential damages in the United States. 1 We reported that, according to the two national-scale studies available at the time that examined the economic effects of climate change across U.S. sectors, potential economic effects could be significant and these effects will likely increase over time for most of the sectors analyzed. 1 For example, for 2020 through 2039, one of the studies estimated from $4 billion to $6 billion in annual coastal property damages from sea level rise and more frequent and intense storms. 1 In addition, the national-scale studies we reviewed and several experts interviewed for the September 2017 report suggested that potential economic effects could be unevenly distributed across sectors and regions. For example, one of the studies estimated that the Southeast, Midwest, and Great Plains regions will likely experience greater combined economic effects than other regions, largely because of coastal property damage in the Southeast and changes in crop yields in the Midwest and Great Plains (see figure 1). 2 This is


2These national-scale studies were the Environmental Protection Agency’s Climate Change Impacts and Risk Analysis—a summary study of an ongoing EPA project—and the Rhodium Group’s American Climate Prospects. See Environmental Protection Agency, Office of Atmospheric Programs, Climate Change in the United States: Benefits of Global Action, EPA 430-R-15-001 (Washington, D.C., 2015). The EPA project on which the summary study was based was coordinated by EPA’s Office of Atmospheric Programs—Climate Change Division, with contributions from national laboratories and the academic and private sectors. The detailed methods and results of the project were published in a 2014 special issue of the peer-reviewed journal, Climatic Change entitled, “A Multi-Model Framework to Achieve Consistent Evaluation of Climate Change Impacts in the United States.” An update to this project was used in the 2018 Fourth National Climate Assessment. Also see Rhodium Group, LLC, American Climate Prospects: Economic Risks in the United States (New York, October 2014). The American Climate Prospects was funded by the Risky Business Project, a project funded by Bloomberg Philanthropies, the Paulson Institute, and TomKat Charitable Trust, the Siefert Global Threats Fund; and the Rockefeller Family Fund. The Rhodium Group, LLC, a research consultancy and advisory company, coordinated the effort, which involved authors from universities and the private sector. This study was later published by the Columbia University Press in 2015. Trevor Houser et al., Economic Risks of Climate Change: An American Prospective (New York: Columbia University Press, 2015). An update to this analysis was published in Science in June 2017: Solomon Hsiang et al. “Estimating Economic Damage from Climate Change in the United States,” Science, vol. 355 (2017).

3Rhodium Group, American Climate Prospects.

4Rhodium Group, American Climate Prospects.
consistent with the findings of the Fourth National Climate Assessment. For example, according to that assessment, the continued increase in the frequency and extent of high-bide flooding due to sea level rise threatens America’s trillion-dollar coastal property market and public infrastructure sector.

Figure 1: Examples of Potential Economic Effects from Climate Change by 2100

As we reported in September 2017, information on the potential economic effects of climate change could help federal decision makers better manage climate risks, according to leading practices for climate risk management. Economic analysis we reviewed, and the views of several

Dr. R. Raadmiller et al., Fourth National Climate Assessment, Volume II.
experts we interviewed. For example, such information could inform
decision makers about significant potential damages in different U.S.
sectors or regions. According to several experts and our prior work, this
information could help federal decision makers identify significant climate
priorities as an initial step toward managing climate risks. Such a first
step is consistent with leading practices for climate risk management and
federal standards for internal control. For example, leading practices
from the National Academies call for climate change risk management
efforts that focus on where immediate attention is needed. As noted in
our September 2017 report, according to a 2010 National Academies
report, other literature we reviewed, and several experts we interviewed,
to make informed choices, decision makers need more comprehensive
information on economic effects to better understand the potential costs
of climate change to society and begin to develop an understanding of the
benefits and costs of different options for managing climate risks.

\[^{11}\text{In that report, we also found that additional economic information could help federal state, local, and private sector decision makers manage climate risks that drive federal fiscal exposure. GAO-17-720.}\]
\[^{13}\text{National Research Council of the National Academies, America’s Climate Choices: Panel on Adapting to the Impacts of Climate Change, Adapting to the Impacts of Climate Change (Washington, D.C., 2010).}\]
\[^{14}\text{GAO-17-720.}\]
The Federal Government Faces Fiscal Exposure from Climate Change Risks, but Does Not Have Certain Information Needed to Help Make Budget Decisions

The federal government faces fiscal exposure from climate change risks in a number of areas, and this exposure will likely increase over time, as we concluded in September 2017. In the March 2019 update to our High-Risk List, we summarized our previous work that identified several of these areas across the federal government, including programs related to the following:

- **Disaster aid.** The rising number of natural disasters and increasing reliance on federal assistance are a key source of federal fiscal exposure, and this exposure will likely continue to rise. Since 2005, federal funding for disaster assistance is at least $450 billion. In September 2018, we reported that four hurricane and wildfire disasters in 2017 created an unprecedented demand for federal disaster resources and that hurricanes Harvey, Irma, and Maria ranked among the top five costliest hurricanes on record.

Subsequently, the fall of 2018 brought additional catastrophic

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9We have identified other areas with potential links to climate and the federal budget in prior reports, including global migration, state and local infrastructure, federal supply chains, and public health. See GAO, Climate Change: Activities of Selected Agencies to Address Potential Impact on Global Migration, GAO-19-169 (Washington, D.C., Jan. 17, 2019); Climate Information: A National System Could Help Federal, State, Local, and Private Sector Decision Makers Use Climate Information, GAO-16-37 (Washington, D.C., Nov. 23, 2015); Federal Supply Chains: Opportunities to Improve the Management of Climate-Related Risks, GAO-16-32 (Washington, D.C., Oct. 13, 2015); and Climate Change: HHS Could Take Further Steps to Enhance Understanding of Public Health Risks, GAO-16-122 (Washington, D.C., Oct. 5, 2015). We also have ongoing work in many areas related to federal fiscal exposure to climate change, examining issues such as how to identify and prioritize resilience projects to build resilience to climate change impacts, how to make water infrastructure more resilient to the impacts of climate change, and how to help communities voluntarily relocate to avoid climate change impacts.

10This total includes, for fiscal years 2005 through 2014, $278 billion that GAO found that the federal government had obligated for disaster assistance. See GAO, Federal Disaster Assistance: Federal Departments and Agencies Obligated at Least $277.6 Billion during Fiscal Years 2005 through 2014, GAO-15-797T (Washington, D.C., Sept. 22, 2015). It also includes, for fiscal years 2015 through 2018, $124 billion in select supplemental appropriations to federal agencies for disaster assistance, approximately $7 billion in annual appropriations to the Disaster Relief Fund (a total of $28 billion for the 4-year period). For fiscal years 2015 through 2018, it does not include other annual appropriations to federal agencies for disaster assistance. Lastly, on June 6, 2019, the Additional Supplemental Appropriations for Disaster Relief Act of 2019 was signed into law, which provides approximately $19.1 billion for disaster assistance. H.R. 2137, 116th Cong. (2019) (enacted).

disasters such as Hurricanes Florence and Michael and devastating California wildfires, with further needs for federal disaster assistance. Disaster costs are projected to increase as certain extreme weather events become more frequent and intense due to climate change—as observed and projected by USGCRP. In July 2015, we reported that the federal government does not adequately plan for disaster resilience and that most federal funding for hazard mitigation is available after a disaster. In addition, our prior work found that the Federal Emergency Management Agency’s (FEMA) indicator for determining whether to recommend that a jurisdiction receive disaster assistance—which was set in 1986—is artificially low because it does not accurately reflect the ability of state and local governments to respond to disasters. Without an accurate assessment of a jurisdiction’s capability to respond to a disaster without federal assistance, we found that FEMA runs the risk of recommending that the President award federal assistance to jurisdictions that have the capability to respond and recover on their own.

- Federal insurance for property and crops. The National Flood Insurance Program (NFIP) and the Federal Crop Insurance Corporation are sources of federal fiscal exposure due, in part, to the vulnerability of the insured property and crops to climate change. These programs provide coverage where private markets for insurance do not exist, typically because the risk associated with the property or crops is too great to privately insure at a cost that buyers are willing to accept. From 2013 to 2017, losses paid under NFIP and the Federal Crop Insurance Program averaged $5 billion per year.

20Jerry M. Melillo, et. al., Climate Change Impacts in the United States: The Third National Climate Assessment.
23The NFIP is administered by FEMA within the U.S. Department of Homeland Security, and the Federal Crop Insurance Corporation is administered by the Risk Management Agency within the U.S. Department of Agriculture.
the federal crop insurance program totaled $51.3 billion. Federal flood and crop insurance programs were not designed to generate sufficient funds to fully cover all losses and expenses, which means the programs need budget authority from Congress to operate. The NFIP, for example, was about $21 billion in debt to the Treasury as of April 2019. Further, the Congressional Budget Office estimated in May 2019 that federal crop insurance would cost the federal government an average of about $8 billion annually from 2019 through 2029.

- Operation and management of federal property and lands. The federal government owns and operates hundreds of thousands of facilities and manages millions of acres of land that could be affected by a changing climate and represent a significant federal fiscal exposure. For example, the Department of Defense (DOD) owns and operates domestic and overseas infrastructure with an estimated replacement value of about $1 trillion. In September 2018, Hurricane Florence damaged Camp Lejeune and other Marine Corps facilities in North Carolina, resulting in a preliminary Marine Corps repair estimate of $3.6 billion. One month later, Hurricane Michael devastated Tyndall Air Force Base in Florida, resulting in a preliminary Air Force repair estimate of $3 billion and upwards of 5 years to complete the work. In addition, we recently reported that the federal government manages about 650 million acres of land in the United States that could be vulnerable to climate change, including the possibility of more frequent and severe droughts and wildfires. Appropriations for federal wildland fire management activities have increased

24FEMA and Risk Management Agency published data. This does not include the costs of running these programs or the premiums collected to partially offset the costs. Losses for the crop insurance program are losses associated with crops harvested in that year, also known as crop year.


considerably since the 1990s, as we and the Congressional Research Service have reported.28

Although the federal government faces fiscal exposure from climate change across the nation, it does not have certain information needed by policymakers to help understand the budgetary impacts of such exposure.29 We have previously reported that the federal budget generally does not account for disaster assistance provided by Congress—which can reach tens of billions of dollars for some disasters—or the long-term impacts of climate change on existing federal infrastructure and programs.30 For example, as we reported in April 2018, the Office of Management and Budget’s (OMB) climate change funding reports we reviewed did not include funding information on federal programs with significant fiscal exposures to climate change identified by OMB and others—such as domestic disaster assistance, flood insurance, and crop insurance.31 A more complete understanding of climate change fiscal exposures can help policymakers anticipate changes in future spending and enhance control and oversight over federal resources, as we reported in October 2013.32 For budget decisions for federal programs with fiscal exposure to climate change, we found in the April 2018 report that information that could help provide a more complete understanding would include: (1) costs to repair, replace, and improve the weather-related resilience of federally-funded property and resources; (2) costs for

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29In our past work, we identified broad principles for an effective budget process, including that it should (1) provide information about the long-term effects of decisions; (2) provide information necessary to make important trade-offs between spending with long-term benefits and spending with short-term benefits, and (3) provide for accountability and be transparent, among other principles. Further, in October 2013, we reported that incorporating more complete information on fiscal exposures could help meet these principles for an effective budget process. See GAO, Budget Process: Enforcing Fiscal Choices, GAO-13-610T (Washington, D.C., May 4, 2013) and GAO, Fiscal Exposures: Improving Cost Recognition in the Federal Budget, GAO-14-28 (Washington, D.C.: Oct. 29, 2013).

30GAO-14-504T.


32GAO-14-28.
Federal Investments in Resilience to Climate Change Impacts Have Been Limited

Although the federal government faces fiscal exposure to climate change, its investments in resilience to climate change impacts have been limited. One way to reduce federal fiscal exposure is to enhance resilience by reducing or eliminating long-term risk to people and property from natural hazards. For example, in September 2018 we reported that elevating homes and strengthening building codes in Texas and Florida prevented greater damages during the 2017 hurricane season. In addition, one company participating in a 2014 forum we held on preparing for climate-related risks noted that for every dollar it invested in resilience efforts, the company could prevent $5 in potential losses. Finally, a 2018 interim report by the National Institute of Building Sciences examined a sample of federal grants for hazard mitigation. The report estimated approximate benefits to society (i.e., homeowners, communities, etc.) in excess of costs for several types of resilience projects through the protection of lives and property, and prevention of other losses. For example, while...

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federal flood and crop insurance programs; and (3) costs for disaster assistance programs, among other identified areas of fiscal exposure to climate change. To help policymakers better understand the trade-offs when making spending decisions, we recommended in the April 2018 report that OMB provide information on fiscal exposures related to climate change in conjunction with future reports on climate change funding.
precise benefits are uncertain, the report estimated that for every grant dollar the federal government spent on resilience projects, over time, society could accrue benefits amounting to the following:

- About $3 on average from projects addressing fire at the wildland urban interface, with most benefits (69 percent) coming from the protection of property (i.e., avoiding property losses).
- About $5 on average from projects to address hurricane and tornado force winds, with most benefits (89 percent) coming from the protection of lives. This includes avoiding deaths, nonfatal injuries, and causes of post-traumatic stress.
- About $7 on average from projects that buy out buildings prone to riverine flooding, with most benefits (65 percent) coming from the protection of property.

The interim report also estimated that society could accrue benefits amounting to about $11 on average for every dollar invested in designing new buildings to meet the 2018 International Building Code and the 2018 International Residential Code—the model building codes developed by the International Code Council—with most benefits (46 percent) coming from the protection of property. 33

We reported in October 2009 that the federal government’s activities to build resilience to climate change were carried out in an ad hoc manner and were not well coordinated across federal agencies. 34 Federal agencies have included some of these activities within existing programs and operations—a concept known as mainstreaming. For example, the Fourth National Climate Assessment reported that the U.S. military integrates climate risks into its analysis, plans, and programs, with particular attention paid to climate effects on force readiness, military

33The International Code Council is a member-focused association with over 64,000 members dedicated to developing model codes and standards used in the design, build, and compliance process to construct safe, sustainable, affordable and resilient structures. The report used a twelvel of buildings constructed to a prior generation of codes represented by 1990s-era design and National Flood Insurance Program requirements.

bases, and training ranges.\textsuperscript{43} However, according to the Fourth National Climate Assessment, while a significant portion of climate risk can be addressed by mainstreaming, the practice may reduce the visibility of climate resilience relative to dedicated, stand-alone approaches and may prove insufficient to address the full range of climate risks.\textsuperscript{41}

In addition, as we reported in March 2019, the Disaster Recovery Reform Act of 2018 (DRRA) was enacted in October 2018, which could improve state and local resilience to disasters. DRRA, among other things, allows the President to set aside, with respect to each major disaster, a percentage of the estimated aggregate amount of certain grants to use for pre-disaster hazard mitigation and makes federal assistance available to state and local governments for building code administration and enforcement.\textsuperscript{45} However, it is too early to tell what impact the implementation of the act will have on state and local resilience.

The federal government has made some limited investments in resilience and DRRA could enable additional improvements at the state and local level. However, we reported in September 2017 that the federal government had not undertaken strategic government-wide planning to manage significant climate risks before they become fiscal exposures.\textsuperscript{42}

We also reported in July 2015 that the federal government had no comprehensive strategic approach for identifying, prioritizing, and

\textsuperscript{43}Lempert, R., J. Arnold, R. Pulwarty, K. Gordon, K. Greg, C. Hawkins Hoffman, D. Sands, and C. Werrell. 2013. Reducing Risks Through Adaptation Actions, in Impact, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II (Washington, D.C.: U.S. Global Change Research Program, 2013). We also reported in May 2014 that officials from the Office of the Secretary of Defense and the military departments stated that their goal is to address potential climate change impacts and vulnerabilities through existing infrastructure planning processes so that the effects of climate change are considered in the same way other impacts and vulnerabilities—such as force protection—are currently considered. GAO, Climate Change Adaptation: DOD Can Improve Infrastructure Planning and Processes to Better Account for Potential Impacts, GAO-14-440 (Washington, D.C., May 30, 2014).


\textsuperscript{43}GAO-17-720.
implementing investments for disaster resilience.\textsuperscript{44} As an initial step in managing climate risks, most of the experts we interviewed for the September 2017 report told us that federal decision makers should prioritize risk management efforts on significant climate risks that create the greatest fiscal exposure.\textsuperscript{45} However, as we reported in our March 2019 High-Risk List, the federal government had not made measurable progress since 2017 to reduce fiscal exposure in several key areas that we have identified.\textsuperscript{46} The High-Risk List identified Limiting the Federal Government’s Fiscal Exposure by Better Managing Climate Change Risks as an area needing significant attention because the federal government has regressed in progress toward one of our criterion for removal from the list.\textsuperscript{47}

\textsuperscript{44}In our 2015 report, we recommended that the Mitigation Framework Leadership group—an interagency body chaired by FEMA—create a National Mitigation Investment Strategy to help federal, state, and local officials plan for and prioritize disaster resilience. In response, the Mitigation Framework Leadership Group developed a draft, high-level strategy. FEMA officials expect to publish the final version of the strategy by July 2016. However, this draft strategy does not explicitly address future climate change risks.

\textsuperscript{45}GAO-15-515.

\textsuperscript{46}GAO-19-157SP.

\textsuperscript{47}We update our High-Risk List every 2 years. To determine which federal government programs and functions should be designated high-risk, we consider qualitative factors such as whether the risk could result in significantly impaired service, or significantly reduced economy, efficiency, or effectiveness, the exposure to loss in monetary or other quantitative terms, and corrective measures planned or under way. We have issued the following five criteria for an area to be removed from the list: leadership commitment, capacity, action plan, monitoring, and demonstrated progress. In the March 2019 report, the federal government regressed in progress toward meeting the monitoring criterion for the Limiting the Federal Government’s Fiscal Exposure by Better Managing Climate Change Risks high-risk area. Criteria for removing this area from the High-Risk List include demonstrating leadership commitment that is sustained and enhanced to address all aspects of the federal fiscal exposure to climate change cohesively.
The Federal Government Could Reduce Its Fiscal Exposure by Focusing and Coordinating Federal Efforts

As we reported in March 2019, the federal government could reduce its fiscal exposure to climate change by focusing and coordinating federal efforts.\footnote{GAO-19-1575P.} However, the federal government is currently not well organized to address the fiscal exposure presented by climate change, partly because of the inherently complicated and crosscutting nature of the issue. We have made a total of 62 recommendations related to limiting the federal government’s fiscal exposure to climate change over the years, 12 of which have been made since February 2017. As of December 2018, 25 of these recommendations remained open. In describing what needs to be done to reduce federal fiscal exposure to climate change, our March 2019 High-Risk report discusses many of the open recommendations.\footnote{GAO-19-1575P.} Implementing these recommendations could help reduce federal fiscal exposure. Several of them, including those highlighted below, identify key government-wide efforts needed to help plan for and manage climate risks and direct federal efforts toward common goals, such as improving resilience:

- **Develop a national strategic plan:** In May 2011, we recommended that appropriate entities within the Executive Office of the President (EOP), including OMB, work with agencies and interagency coordinating bodies to establish federal strategic climate change priorities that reflect the full range of climate-related federal activities, including roles and responsibilities of key federal entities.\footnote{GAO-11-317} Such federal responses could include establishing a strategy to identify, prioritize, and guide federal investments to enhance resilience against future disasters.

- **Use economic information to identify and respond to significant climate risks:** In September 2017, we recommended that the appropriate entities within EOP use information on the potential economic effects of climate change to help identify significant climate risks facing the federal government and craft appropriate federal responses.\footnote{GAO-17-720}
• Provide decision makers with the best available climate information: In November 2015, we reported that federal efforts to provide information about climate change impacts did not fully meet the climate information needs of federal, state, local, and private sector decision makers, which hindered their efforts to plan for climate change risks.20 We reported that these decision makers would benefit from a national climate information system that would develop and update authoritative climate observations and projections specifically for use in decision-making. As a result, we recommended that EOP (1) designate a federal entity to develop and periodically update a set of authoritative climate observations and projections for use in federal decision-making, which other decision makers could also access; and (2) designate a federal entity to create a national climate information system with defined roles for federal agencies and nonfederal entities with existing statutory authority.21

• Consider climate information in design standards: In November 2016, we reported that design standards, building codes, and voluntary certifications established by standards-developing organizations play a role in ensuring the resilience of infrastructure to the effects of natural disasters. However, we reported that these organizations faced challenges to using forward-looking climate information that could help enhance the resilience of infrastructure. As a result, we recommended in the November 2016 report that the Department of Commerce, acting through the National Institute of Standards and Technology—which is responsible for coordinating federal participation in standards organizations—convene federal agencies for an ongoing government-wide effort to provide the best available forward-looking climate information to standards-developing organizations for their consideration in the development of design standards, building codes, and voluntary certifications.22

In conclusion, the effects of climate change have already and will continue to pose risks that can create fiscal exposure across the federal government and this exposure will continue to increase. The federal

21EOP neither agreed nor disagreed with these recommendations and as of March 2019, had not implemented them.
government does not generally account for such fiscal exposure to
programs in the budget process nor has it undertaken strategic efforts to
manage significant climate risks that could reduce the need for far more
costly steps in the decades to come. To reduce its fiscal exposure, the
federal government needs a cohesive strategic approach with strong
leadership and the authority to manage risks across the entire range of
related federal activities. The federal government could make further
progress toward reducing fiscal exposure by implementing the
recommendations we have made.

Chairman Yarmuth, Ranking Member Womack, and Members of the
Committee, this completes my prepared statement. I would be pleased to
respond to any questions that you may have at this time.

GAO Contact and Staff
Acknowledgments

If you or your staff have any questions about this testimony, please
contact me at (202) 512-3841 or gomez@gao.gov. Contact points for our
Offices of Congressional Relations and Public Affairs may be found on
the last page of this statement. GAO staff who made key contributions to
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Chairman YARMUTH. Thank you, Mr. Gómez.
I now recognize Mr. Cass for five minutes.

STATEMENT OF OREN CASS

Mr. Cass. Thank you, Chairman Yarmuth, Member Johnson, and all Members of the Committee, for inviting me to testify today. My written testimony discusses climate economics, estimates of climate costs, and appropriate policy responses. I would like to use my brief time here to provide a concrete illustration of one point in particular: the way in which cost estimates go astray when they fail to account for adaptation, meaning they model an implausible future in which human society takes no action to protect itself against the potential harms of a warming climate.

I will describe one climate cost in particular, which is called extreme temperature mortality—or, in other words, people dying from very high or low temperatures. Both of the government's major synthesis reports, Dr. Hayhoe's National Climate Assessment and Mr. Gómez's GAO report, suggest that heat deaths will be one of the largest costs and, in some cases, the largest cost of climate change. Both rely on estimates from the same two studies: one from EPA’s CIRA project, and one published by Dr. Hsiang and his colleagues. So let’s take a look at those estimates.

First, EPA’s CIRA. The model here considers extreme heat, city by city. It takes each city’s range of temperatures and defines the top 1 percent of low temperatures as extremely hot. Cities tend to experience elevated mortality on such days. So, for Pittsburgh in 2000, as you see illustrated here, a day with a low temperature above 71 degrees would count.

Next, the study applies a projection of warming temperatures under climate change, but it does not update the threshold for a very hot day. Even as the climate warms, the study assumes that Pittsburgh will still react to every day with a low above 71 as extremely hot. The result is many more such days, as you see in the red compared to the blue, and an enormous increase in deaths. The result does not make sense. The three bars on the left here show the extreme temperature mortality from the study in 2000 for some of the nation’s hottest cities: Phoenix, Houston, and New Orleans. The three bars on the right show the projected mortality rate in 2100 from the study for some northern cities: New York, Detroit, and Pittsburgh. Those cities will not be as hot in 2100, as our southern cities are today, yet EPA claims people could be dying at a rate 50 to 75 times higher. The technical term for this is “a bad model.” Yet EPA, GAO, and the National Climate Assessment all reported uncritically.

The second estimate comes from work by Dr. Hsiang and his colleagues published most recently in the journal, “Science.” The approach here is different, assuming that all places react the same way to extremely hot days. Because climate change will create the most and hottest days in the South, therefore, you see on the left side of the chart the dark red areas of much higher mortality in the South. The right side shows the study’s total estimate of climate cost, also used by the National Climate Assessment. As temperatures get warmer, cost rises, and the blue section—virtually the entire cost—comes from this heat-related mortality.
Now, I would like to show how these estimates might change if we take adaptation into account.

First, consider a related study by Barreca et al., that looked at adaptation that has already occurred. For the United States they found that, “The impact of days with a mean temperature exceeding 80 degrees Fahrenheit has declined by about 75 percent over the course of the 20th century,” and that, at 2004 rates of air conditioning, it may even be the case that such days would have “no impact on mortality.” “It is apparent,” they write, that “air conditioning has positioned the United States to be well-adapted to the high-temperature-related mortality impacts of climate change.” Notably, the science estimate on the left side uses the data from the study on the right, it just doesn’t use the finding that a focus on the most recent data reduces mortality substantially.

One more example of how adaptation assumes—assumptions affect climate. On the right side is a result from a Climate Impact Lab working paper published last year. Here the authors do focus on adaptation and, importantly, the costs of adaptation, as well as the benefits. We shouldn’t forget that adaptation has costs, as well.

But compare the measure of climate change’s effect on the southeast, on the left, with no adaptation, to the effect on the right, with adaptation. Now the southeast is blue. It appears to actually benefit from climate change. The authors write, “Failing to account for income and climate adaptation, as has been the norm in the literature”—and here they specifically the—cite the study on the left—“would overstate the mortality costs of climate change by a factor of about 3.5.”

Speaking specifically about the southeast U.S., they say it is, “currently so heavily adapted to hot climates” that “additional warming leads to limited additional mortality or adaptation costs.” These locations then end up benefitting from reductions in a relatively small number of cold days.

Let me conclude by emphasizing that none of this means that climate change is not a serious problem or does not require a policy response. It is, and it does. But in thinking about it, and responding to it, we should recognize that our society has shown a remarkable capacity to adapt to and thrive in a wide variety of climates, some quite hostile, for significant periods of the year.

[Charts].
Effect of extreme temperature on mortality
Effect of extreme temperature on mortality
Effect of extreme temperature on mortality

Estimated net mortality from extremely hot and cold days (deaths per 100,000 residents)

- Phoenix (2000): 0.17
- Houston (2000): 0.16
- New Orleans (2000): 0.21
- Pittsburgh (2100): 12.83
- Detroit (2100): 9.19
- New York (2100): 8.92
Effect of extreme temperature on mortality, take two

Figure 2B: Spatial distributions of projected damages.


Figure 5B: Estimates of total direct economic damage from climate change.

B
Effect of extreme temperature on mortality, take two

The impact of days with a mean temperature exceeding 80°F has declined by about 75 percent over the course of the twentieth century in the United States, with almost the entire decline occurring after 1960.

At 2004 rates of residential AC adoption, the null hypothesis that additional 80°F–89°F and >90°F days would have no impact on mortality cannot be rejected. It is apparent that air conditioning has positioned the United States to be well adapted to the high-temperature-related mortality impacts of climate change.


Effect of extreme temperature on mortality, take two

Figure 2B: Spatial distributions of projected damages.

Figure 9: Spatial distribution of the marginal mortality damages due to a 1t CO2 emissions increase.


Effect of extreme temperature on mortality, take two

Figure 2B: Spatial distributions of projected damages.

Further, failing to account for income and climate adaptation as has been the norm in the literature (Deschenes and Greenstone, 2011; Hsiang et al., 2017) would overstate the mortality costs of climate change by a factor of about 3.5..."

Several regions that are relatively wealthy and hot today (e.g. Australia, Saudi Arabia, Southeastern US) are currently so heavily adapted to hot climates that their response functions are already relatively shallow at the hot end, so additional warming leads to limited additional mortality or adaptation costs — these locations then end up benefiting from reductions [in] a relatively small number of cold days.

Climate costs can be real without being catastrophic

Source: Shawn Reynolds, (@ShawnReynolds), Jan 7, 2014
Further, our population continues shifting toward the South, actively seeking out warmer climates. Cost estimates that do not account for adaptation are not good estimates, and reports that rely on such estimates can be misleading to policymakers and the public. Thank you very much.

[The prepared statement and report of Oren Cass follows:]
Testimony

The Costs of Climate Change: Risks to the U.S. Economy and the Federal Budget

Oren M. Cass
Senior Fellow, Manhattan Institute for Policy Research

Before the
Committee on the Budget
United States House of Representatives

June 11, 2019
Chairman Yarmuth, Ranking Member Womack, and Members of the Committee, thank you for inviting me to participate in today’s hearing.

I have asked Ranking Member Womack to introduce into the record a report that I published last year, titled “Overheated: How Flawed Analyses Overestimate the Costs of Climate Change.” The report examines in detail the U.S. Government Accountability Office’s 2017 report, titled “Climate Change: Information on Potential Economic Effects Could Help Guide Federal Efforts to Reduce Fiscal Exposure”; the synthesis reports relied upon by GAO; and the underlying reports relied upon by those syntheses. This testimony draws on the report’s analyses and conclusions.

I hope to convey three important ideas to the committee:

- First, **climate science and climate economics are very different fields.** Climate science makes scientific observations about predictions about physical changes and deserves substantial deference from policymakers. Climate economics does not.

- Second, **the best estimates of climate costs are modest in scale** when placed in proper context. This requires accounting for both future growth and adaptation.

- Third, **none of this means that climate change is not a serious problem or that it does not require a policy response; it is and it does.** In formulating that response, policymakers must recognize that costly efforts to reduce U.S. emissions do not eliminate future costs that are driven by global emissions. They must consider the full range of options—adaptation as well as mitigation, nuclear as well as renewables. In the many cases where adaptation can prove critical, they must ensure that private actors have the right information and incentives to adapt.

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I. Climate Science versus Climate Economics

Climate scientists have spent decades studying and modeling changes in the Earth’s climate and have built substantial consensus around a number of points that are of relevance to policymakers, for instance: that the climate is warming, that human activity is responsible for most of that warming and likely responsible for almost all of it, and that continued emissions will lead to several degrees of warming this century. These points are well-documented in synthesis reports like the United Nations Intergovernmental Panel on Climate Change’s Fifth Assessment Report® [IPCC] and the U.S. Global Change Research Program’s Fourth National Climate Assessment® [NCA]. The scientific conclusions in these reports are generally balanced, measured, and carefully substantiated. As with other insights from the scientific world, they should be the starting point for political debates about how to respond, not topics of political debate themselves.

Likewise, these insights provide the starting point for the separate field of climate economics. Unlike climate science, climate economics is not a scientific enterprise, it has not established areas of substantial and long-standing consensus, and it is not owed deference by policymakers and analysts. To the contrary, climate economics requires fundamental and often contested judgments about how the physical changes predicted by climate science will ultimately affect human society via their influence on public health or infrastructure or the economy. It depends upon assumptions about future economic growth and technological progress, the ways in which societies will adapt to changes in the climate, and thus how the physical world’s changes will eventually be felt in the future.

Today’s hearing, titled “The Costs of Climate Change: Risks to the U.S. Economy and the Federal Budget,” invites a discussion about climate economics. What climate change will cost and what risks it will pose to the economy and the budget are questions for policymakers to grapple with, just as they grapple every day with equivalent questions about countless other challenges.

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II. Estimates of Climate Costs

The cost estimates created by climate economics are easily misinterpreted. Take, for instance, the New York Times coverage of the NCA’s release in November 2018. The online headline read: “U.S. Climate Report Warns of Damaged Environment and Shrinking Economy.” That was not correct. While the report describes substantial climate-related costs and the possibility that U.S. Gross Domestic Product will be lower than in a no-climate-change world, nowhere does it suggest that the economy will have ceased to grow and begun to decline because of climate change.

How much does the NCA say climate change will cost? In its print edition, the Times gave the story top billing on the front page, with a subhead that warned of a “Reduction of Up to 10 Percent of GDP.” That was misleading. The “10 Percent” number came from the report’s Figure 29.3, in turn taken from a 2017 article published in Science. That figure shows an estimated relationship between climatic warming and damage to the U.S. economy as a percentage of GDP. On the chart’s far-right edge, a single datapoint connects warming of 14-15°F (8°C) with projected damage equal to roughly 10% of GDP.

But that level of warming is not contemplated by the NCA. In its “Higher Scenario,” the NCA estimates warming by century’s end of only 2.4-4.7°C, which would correspond in its damage chart to roughly 1-4% of GDP. This did not stop Senator Ed. Markey (D-MA) from announcing via Twitter that “According to the Trump admin’s National Climate Assessment, with no action, climate change will result in 10% GDP loss by 2090,” and that “A #GreenNewDeal addresses this climate reality” (emphasis added)."12

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5 NCA Vol II, ch. 2, fig. 2.2.

6 @SenMarkey (Senator Ed Markey). “Climate change is literally destroying the planet. According to the Trump admin's National Climate Assessment, with no action, climate change will result in 10% GDP loss by 2090. A #GreenNewDeal addresses this climate reality, not right-wing misinformation.” Twitter, February 28, 2019, 3:57 p.m., https://twitter.com/EdMarkey/status/1107249200866839963.
Accounting for Future Growth

Correctly understanding that the report estimates damage on the order of 3% of GDP still leaves the question: Is 3% a lot? On one hand, obviously yes. According to the EPA report on which NCA relies for many of its cost estimates, U.S. GDP should grow to roughly $80 trillion by 2100 from roughly $20 trillion today. Three percent of that total would be more than $2 trillion.

On the other hand, $80 trillion is a much larger number, describing an America four times wealthier than the present day. A $2 trillion reduction in that prosperity represents the difference between a future, climate-change-free America that might be 4.0x wealthier than today’s and a climate-change-affected America that might be 3.9x wealthier. Costly, but hardly catastrophic.

Another way to understand the cost is in temporal terms. Per EPA (and notwithstanding the New York Times), the economy will still be growing. Assuming even a modest 1.5% annual growth rate, the damage from climate change represents two years of growth. In other words, a climate-change-affected America might not achieve until 2102 the level of economic prosperity that a climate-change-free America might achieve by 2100.

In a 2016 report, the President Barack Obama’s Office of Management and Budget studied climate change’s impact on the federal budget. The report provided an estimate for “late-century” of $54-112 billion in climate-related costs, which it then calibrated to account for economic growth. Placed in the context of the present-day economy and budget, its estimate was $9–28 billion with a mid-point of $16.3 billion. That, again, is a substantial amount of money. But, again, some perspective is in order. The U.S. Department of the Treasury estimates that the IRS made improper payments worth $18.4 billion through the Earned Income Tax Credit in 2018. The Centers for Medicare & Medicaid Services estimates that Medicare made improper payments worth $31.6 billion. Neither is an “existential threat.”

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Accounting for Adaptation

Even in its proper context, the NCA’s cost estimates are still implausibly high, because they fail to account for adaptation. In other words, the economic models that produce the cost estimates work from an assumption that Americans will make no adjustments in their lives to account for changes in their climate. Bizarre though this may seem, the assumption is well understood and accepted within the world of climate economics. In the fine print beneath the NCA’s colorful graphic depicting climate costs, it notes that “results assume limited or no adaptation.”

Yet some of the key studies that drive the NCA’s cost estimates do provide estimates that account for adaptation, and in doing so illustrate why it must always be considered. For instance, the NCA offers an estimate of $141 billion in annual economic damage from extreme temperature mortality in 2090. But according to the EPA study that the NCA relies on, adaptation could reduce the damage by more than half. NCA offers an estimate of $118 billion for coastal property damage, but EPA says adaptation could reduce the damage by more than three-quarters.

More generally, while extreme temperature mortality — that is, an increase in the number of hot days leading to an increase in death rates — is usually among the largest drivers of cost estimates, recent studies accounting for adaptation find almost no effect from climate change or even a reverse effect — that is, a reduction in mortality due to fewer cold days.

Climate change will have real costs. Importantly, adaptation itself comes with costs that must be accounted for. But with adaptation, total costs will be much smaller than the headline-grabbing numbers that climate economists and our government agencies choose to highlight, and with future growth our society will be far better equipped to handle them.

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17 NCA Vol. II, fig. 29.2.
18 EPA 2017, tbl. 5.2.
III. Policy Responses

While warnings of climate catastrophe are not supported by the available evidence, climate change does pose real challenges that will require policy responses. Effective responses will be ones that approach climate change rationally and have the potential to substantially reduce climate-related costs, without using the issue as a pretext for tackling any number of ancillary priorities. In many cases, these policies will emphasize adaptation (that is, coping cost-effectively with the climate change that occurs) rather than mitigation (that is, trying to prevent climate change from occurring).

Identifying Benefits

Evaluations of climate policy proposals make a common error by measuring the cost to the United States of unmitigated climate change against the cost of eliminating American emissions. Finding the latter cost to be purportedly lower, the analyst declares the action worthwhile. But:

Incurring the cost to eliminate American emissions may not eliminate—or even reduce substantially—the climate-related costs that the United States will incur.

This is because the rate of climate change is driven by global emissions, of which the American share is small and declining. The United States could eliminate all of its emissions tomorrow and climate change would proceed more or less apace.

To properly assess the costs and benefits associated with a given climate policy proposal, its proponents need to provide an estimate of the amount by which global emissions will be lower thanks to the policy, the amount by which warming might therefore be lessened, and the amount by which forecasted damage might therefore be reduced. Note that advocates rarely do this. Whether the policy under consideration is a carbon tax or a “Green New Deal,” the cost of climate change is asserted and the cost of American action is asserted... nowhere is an actual climate benefit asserted. That’s because there is very little.

To meaningfully alter the trajectory of global emissions for the coming century, the developing economies that are building the energy infrastructure that they will operate for decades to come must begin adopt emissions-free technologies. They will do this only if those technologies are cheaper and easier to use than fossil fuels, which today they are not. Building a marginal unit of renewable energy may in many cases be economically attractive, but no path yet exists to using intermittent technologies like wind and solar power for providing the dependable baseload that an industrial economy must rely on at all times. That’s why coal’s share of global power generation
remains unchanged from 20 years ago\textsuperscript{22} and China is still investing aggressively in coal power plants.\textsuperscript{23} Clean energy investment, by contrast, has been declining since 2015 and is lower in both Asia and Europe than when the Paris Agreement was signed; solar investment in Asia has fallen for seven straight quarters.\textsuperscript{24}

\textit{Mitigation through innovation}

Any strategy for mitigation must focus obsessively on technological innovation—not the deployment of ever more wind and solar, but the development of new technologies with greater potential. The United States has already been subsidizing wind and solar technologies for decades but, as Bill Gates observed in a recent discussion at Stanford University, they are not going to provide the solution. “The idea that we have the current tools and it’s just because these utility people are evil people and if we could just beat on them and put (solar panels) on our rooftop—that is more of a block than climate denial,” said Gates. “The ‘climate is easy to solve’ group is our biggest problem.”\textsuperscript{25}

Resources should instead be directed toward research and development for new technologies. Subsidies, likewise, should be focused on new technologies trying to make their initial entry into the market. The subsidies should be time-limited, so that developers know they must find a path to economic viability rather than build business models that rely on endless government support. They should also be technology-neutral, so that any new low-emissions technology capable of replacing a high-emissions one is accorded equal treatment.

Nuclear power, in particular, must be given greater attention. Nuclear power may not prove to be a major, enduring component of the world’s energy portfolio, but it has the potential. At a minimum, existing nuclear plants should be kept operating where possible and innovation efforts should embrace new approaches to nuclear power as avenues worth exploring. Nothing exposes the unseriousness of a climate agenda faster than a refusal to discuss nuclear or, worse, an insistence that \textit{shutting down} nuclear is somehow “green.”

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Encouraging Adaptation

Weakness in climate economics is not a reason to abandon efforts at estimating the future costs of climate change. Researchers should continue to study the concrete, human effects likely to emerge from changes in the physical climate and the nature of associated adaptation, as these findings help to identify which climate-related threats are the most severe and which adaptations may require changes in public policy. For example, continued research on sea-level changes and their implications for coastal development will be invaluable to responsible public policy in the decades to come. Policymakers should continue to seek out and consider legitimate cost estimates.

Estimating adaptation costs is important too. While failing to account for adaptation in their top-line cost estimates, many economic analyses do consider adaptation pathways and provide estimates of likely cost—for instance, the effects of extreme temperatures on energy consumption if society adapts through greater use of air conditioning.26 Just because adaptation is desirable and likely to occur does not make it free.

Policymakers should work to ensure that society has the best possible information about likely effects of climate change and the right incentives to take that information into account. Specifically:

- Continue to invest in climate science. If decision-makers from urban planners to farmers to coastal property owners are to make intelligent investments that build resilience and adapt to changes in climate, they will need the best possible forecasts of what those changes are likely to be.

- Focus research directly on adaptation. Rather than accept the convenience of modeling a future without adaptation, emphasize the need for better understanding of adaptation pathways: Where will it occur naturally? Where will it occur but at a cost or only with better policy? In what situations might adaptation be insufficient and what contingency planning is required? Understanding the answers to those questions will highlight the costs that are most concerning and point toward the policy responses that might be most effective. Government agencies should withdraw reports that have failed to account for adaptation and they should require an assumption of adaptation as the default in future cost estimates.

- Ensure that decision-makers have the right incentives to account for climate change and its costs. If government insulates people from the costs of climate change, they will not have sufficient incentive to prepare for the costs or avoid them. Insurance products must accurately reflect risk; the price of water must reflect its supply and demand; urban planners must understand their own cities will be responsible for upgrading infrastructure that they build unwisely.

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26 See, e.g., Deschenes and Greenstone 2011.
Conclusion

The failure to consider adaptation has profound consequences for how people conceptualize climate change, leading to what I call *climate catastrophism*. If the entire brunt of a century of climate change were to land on civilization tomorrow — if a substantial share of agricultural output suddenly vanished, if sea levels were suddenly several feet higher, if regions accustomed to temperate summers suddenly experienced outdoor temperatures to which they were unaccustomed, if hundreds of millions of people were suddenly displaced — the result might well be catastrophic. But if those changes occur gradually (as they are expected to), if they emerge in a world far wealthier and more technologically advanced than today’s (as we expect it to be), and if policymakers ensure that people have the information and incentives to plan well (something over which we have control), then climate change will impose real costs but ones that we should have confidence in our ability to manage.
About the Author

Oren Cass is a senior fellow at the Manhattan Institute, where he focuses on energy, the environment, and antipoverty policy. In 2015, Politico recognized him as one of 50 “thinkers, doers and visionaries transforming American politics.” He has written about climate policy for publications including the Wall Street Journal and Foreign Affairs, testified before House and Senate committees, briefed EPA and White House officials, spoken at MIT and the University of Texas, and appeared on NPR and the BBC. The Washington Examiner’s Byron York called Cass’s analysis “the best commentary on Trump and Paris.”

In 2011–12, Cass was the domestic policy director for Mitt Romney’s presidential campaign, where he shaped campaign policy and communication on issues from health care to energy to trade. Prior to joining the Manhattan Institute, he was a management consultant for Bain & Company in the firm’s Boston and New Delhi offices, where he advised global companies across a range of industries on implementing growth strategies and performance-improvement programs. Cass holds a B.A. in political economy from Williams College and a J.D. from Harvard University, where he was an editor and the vice president of volume 123 of the Harvard Law Review.
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Executive Summary

Prominent recent studies that forecast the cost of human-caused climate change rely on statistical analyses of the effects of temperature variation. These correlation-based, temperature-impact studies—hereinafter referred to as temperature studies—start with present-day relationships between temperatures and outcomes such as mortality or economic growth. They extrapolate from those relationships a proportionally larger response to long-term projected climate warming and assign dollar values to the very large impacts that appear to emerge.

This paper examines a set of such studies that the U.S. Environmental Protection Agency and the U.S. Government Accountability Office have used to estimate the costs of human-caused climate change for the U.S. by the end of the 21st century. The costs include deaths from extreme heat, lost hours of work from extreme heat, and deaths from heat-caused air pollution. The paper also examines another study, published in Nature, that projects the effect of human-caused climate change on global economic production.

Key findings

- Temperature studies do not offer useful projections of deaths and lost hours of work for extreme heat, or deaths due to heat-caused air pollution, in the U.S. The projection of lower global economic output due to projected human-caused climate change is also flawed.

- The crucial though not the only flaw of temperature studies is that they neglect human adaptations to a changing climate. Such adaptations have already been made by industrial societies expanding into warm regions, such as the American South and Southwest. The temporary effects of temperature variations—such as an unusual hot spell—cannot be equated with a long-term change in temperature patterns. For example, the failure of people to install air conditioners in a year with one extra 90°F day does not mean that they won’t do so in the next of 40 extra 90°F days.

- Properly understood, temperature studies do not offer useful predictions of the future costs of projected human-caused climate change.
OVERHEATED: HOW FLAWED ANALYSES OVERESTIMATE THE COSTS OF CLIMATE CHANGE

Introduction

Policymakers use estimates of climate change’s expected effects to assess the magnitude of the challenge and formulate cost-effective responses. Such estimates are inherently speculative: they require the translation of forecasted temperature increases into effects such as rising seas or more frequent droughts, the translation of those effects into impacts on human society such as inundated coastal property or declining agricultural yields, and the translation of those effects into dollar terms. Of course, to be relevant, projections of the societal impact of climate change should provide some account for how society might respond—by building seawalls, improving irrigation, relocating resorts and farms, or even developing entirely new technologies.

Thus, a sea-level study might apply a range of estimated temperatures throughout the 21st century to a model that translates temperature into a rate of ice melt for Greenland and Antarctica and then translates runoff from that melt into a rate of sea-level rise. That estimated rise could be applied to a database of coastal populations and property values at various elevations to determine who and what might be placed at risk and estimate the cost of relocation or constructing barriers. Each assumption along the way can be studied and scrutinized. For instance, scientists have estimated that ice melt in Greenland could contribute between two and six inches of sea-level rise by 2100. But scientists are constantly refining these estimates both higher and lower; one recent analysis finds that models may be overestimating runoff into the ocean by 20% to 60%. Prominent recent studies (see sidebar, Research Discussed in This Report) forecasting the cost of human-caused climate change sidestep this process, instead relying solely on statistical analyses of the effects of temperature variation. These correlation-based, temperature-impact studies—hereinafter referred to as temperature studies—link higher temperatures directly to outcomes such as rising mortality or declining economic growth on the basis of historical correlations and then use those correlations to extrapolate the potential effects of projected temperature increases in the future. For example, if a temperature study were to find that each additional day in a given city or region with an average temperature above 90°F produces an additional 100 fatalities, and climate models forecast an additional 40 such days annually in the area, the study would conclude that the area will experience 4,000 excess fatalities.

If the procedure involved here seems off, that’s because it is. This report explains the technical details of why. But plain common sense can help, too. Temperature studies insist that even marginally warmer temperatures make people and the economy worse off; yet for generations, the American population has insisted on migrating southward. Are people doing so against their best interests, or are the statistical analysts missing the bigger picture?

In any event, cost estimates from temperature studies vastly exceed those from more traditional analyses of climate change’s expected effects on the physical world. Perhaps consequently, these studies have gained rapidly in prominence; they now account for the overwhelming share of costs in climate assessments.

At the request of Senators Maria Cantwell (D., Washington) and Susan Collins (R., Maine), the U.S. Government Accountability Office worked from December 2015 to September 2017 to review “the potential economic effects of climate change impacts and resulting risks to the federal government.” Its report, “Climate Change: Information on Potential Economic Effects Could Help Guide Federal Efforts to Reduce Fiscal Exposure” (GAO), summarized two other studies that drew on and synthesized a further range of studies to provide national-scale estimates of the economic costs of projected climate change for the United States. In both of these synthesis studies,
the largest costs and vast majority of total costs derive from temperature studies that assert correlations between higher temperatures and more extreme heat deaths, more air-pollution deaths, and fewer hours worked. The two synthesis studies C40 relied on are:

- "American Climate Prospectus: Economic Risks in the United States," published in October 2014 by the Rhodium Group (Rhodium), a research consultancy, assesses the economic effects of climate change on coastal property, health, agriculture, energy, labor productivity, and crime. It estimates that by 2100, climate change will cost the U.S. $2.28 trillion–$945 billion per year. At least 71% of this sum is based on the estimates from individual temperature studies.

- "Climate Change in the United States: Benefits of Global Action," published in June 2015 by the U.S. Environmental Protection Agency (EPA), assesses the economic effects of climate change on health, infrastructure, electricity, water resources, agriculture, forestry, and ecosystems. It estimates that by 2100, climate change annually will cost the U.S. $1.3 trillion–$1.5 trillion. At least 89% of this sum comes from temperature studies.

Rhodium and EPA, along with other recent syntheses, share many authors and studies (see Figure 1). They also share a flawed set of underlying assumptions and analyses that render their estimates of future climate costs of no practical use.

The remainder of this paper reviews the studies that account for most of the costs in the Rhodium and EPA estimates, as well as a study published in June 2017 in Science, "Estimating Economic Damage from Climate Change in the United States" (Howe). It also reviews a study published in Nature in November 2015, "Global Non-linear Effect of Temperature on Economic Production" (Burke), that pushes the envelope further in the direction of abstract analysis, yielding even larger but even less credible cost estimates. Each section of this paper takes up a key cost of climate change as estimated by recent temperature studies: heat deaths, labor productivity, air pollution, and the economy.
Climate Change and Mortality

Climate change may increase deaths from extreme heat. This may be offset by reduced deaths from cold, but many studies conclude that on balance, higher temperatures will cause more deaths overall. **Rhodium** and EPA use different studies to establish estimates of heat-related deaths:

- The EPA estimate of costs due to additional heat deaths in 2100 relies on **Mills**. Mills studied the effect on mortality rates from days of “extreme” heat (or cold) in 33 cities, defined, respectively, as days with a low temperature in the warmest 3% of the city’s lows, or a high temperature in the coldest 3% of the city’s highs. In Pittsburgh, for example, 99% of daily low temperatures were less than 21.7°C (71.1°F); a day with a warmer minimum temperature would count as “extremely hot.” For each city, the researchers measured the change in mortality on days with temperature extremes during 1989–2000.

Using climate models, the researchers then estimated for the years 2000 and 2100 a distribution of daily temperatures for each city. In 2000, the climate model’s simulation of Pittsburgh had fewer than five extremely hot days; for 2100, it had approximately 70, each of which Mills assumed would have the elevated mortality level associated with extremely hot days in the past. Overall, Mills estimated that extreme-heat deaths in the 33 cities studied would rise from fewer than 600 in 2000 to more than 7,500 in 2010, even if their populations remained constant.

**EPA** employed the Mills methodology but used a different climate model to forecast the increase in extremely hot days, applied the work to additional cities, and accounted for population growth over the century. In the EPA model, Pittsburgh’s annual death rate from extreme temperatures increases 30-fold, from 0.4 per 100,000 people in 2000 to 12.8 in 2100. Across all cities, excess fatalities by 2100 would exceed 12,000.

The Mills’s estimates of heat deaths exemplify the most severe and off-discussed flaw in temperature studies: the assumption of no adaptation. These studies of temperature effects rely on historical data but attempt to predict the response to temperature variation 100 years later. This is appropriate only on the assumption that society’s reaction to a given variation will be the same at both points in time. That assumption is a poor one.
If global warming makes heat currently regarded as extreme more frequent and less surprising, then temperate cities will almost certainly make adaptations to function better in heat, much as people moving to cities in warmer climates have already done (see sidebar, *Adaptation to a Changing Climate*). But Mills assumes, implausibly, that an anomalous temperature in 2000 does the same harm as an equal, but by then less anomalous, temperature in 2100.

The implausibility of the no-adaptation assumption is laid bare by single-city mortality estimates. EPA uses the model in Mills to estimate 12,000 annual heat deaths nationally in 2100. Much of the estimate stems from temperature increases in northern cities such as Pittsburgh, Detroit, and New York, with forecasted heat-related mortality rates of 12.8, 6.2, and 8.6 per 100,000. Yet southern cities such as Phoenix, Houston, and New Orleans, which were already hotter in 2000 than northern cities are predicted to be in 2100, had mortality rates in 2000 of only 0.2 per 100,000 (see Figure 2).

Mills explained that its main findings “explicitly exclude consideration of the possibility of there being an adaptive response over time to extreme temperatures.” Still, Mills did provide an alternative analysis in which every city increases its extreme-heat threshold to that of present-day Dallas. With this alternative assumption, extreme-heat deaths fell by almost two-thirds.” EPA did not use this result.

- Deschênes-Greenstone underlies the Rhodium estimate of heat deaths due to warming. This study used an approach different from that of Mills; it grouped temperatures into 10-degree-Fahrenheit buckets (70°–80°F, 80°–90°F, >90°F, etc.), counted the days with average temperatures at each level in each U.S. county in each year during 1968–2002, and compared these counts with total mortality rates in each county and year. The researchers found that an additional very cold (<30°F) or very hot (>90°F) day was associated with 0.5–1.0 additional deaths per 100,000 people.¹

Like Mills, Deschênes-Greenstone used climate models to estimate the temperature distribution at the end of the century. Their analysis found that climate change would reduce cold-related deaths somewhat but increase heat-related deaths much more. The average county saw one >90°F day each year during 1968–2002 but would see 44 such days each year during 2070–99.¹ If the danger of experiencing a daily temperature within a given bucket did not change, the result of climate change would be 132,000 more heat-related deaths and 59,000 fewer cold-related deaths each year, for a net impact of 63,000 additional deaths by 2100 (totals do not sum due to rounding).²

Unlike Mills, Deschênes-Greenstone focuses on an absolute threshold of >90°F for an extremely hot day, valid for all locations and times. Whereas Mills assumes that the ability to cope with high temperatures is location-specific and does not change with climate, Deschênes-Greenstone assumes that certain temperatures are more costly everywhere and anytime. This approach has the virtue of allowing the researchers to consider more carefully the effects of climate adaptation because it can compare the future effects of global warming—for example, higher temperatures in northern cities—with conditions that exist today, such as temperatures in southern cities, and thereby assess whether cities in already-hot climates have already made adaptations. Technological advances may further improve adaptation to hot weather, but if a study can at least show that present-day adaptations do not improve hot cities’ resilience, it can better justify high estimates of global warming’s harms.

Deschênes-Greenstone conducted several useful analyses to test for adaptation and found that absolute extreme heat worsened mortality in both hotter and colder climates. Yet their conclusion was undermined by a subsequent paper, Barrera—which is also cited by Rhodium, of which Deschênes and Greenstone themselves are coauthors, and which is discussed next.
Temperature studies insist that even marginally warmer temperatures make people and the economy worse off; yet for generations, the American population has insisted on migrating southward. Are people doing so against their best interests, or are the statistical analysts missing the bigger picture?
Adaptation to a Changing Climate

Why might a society’s response to a given temperature in 2100 differ significantly from its response if that temperature were to occur suddenly in the colder climate of 2018? The answer starts by understanding that potential adaptation has five distinct dimensions:

- **Biophysical**: Humans are not biologically adapted to different temperatures, and their responses to those temperatures differ after extended exposure. This is conventional wisdom for anyone who has ever found the weather in some unaccustomed place unpleasant.

- **Behavioral**: Humans react differently to temperature outside the ordinary. Some of this is purely psychological, while some is quite practical. For example, light snow exposes a unique traffic hazard in areas where drivers are not accustomed to driving in the snow.

- **Technological**: Societies develop and adopt technologies appropriate to their climate. Air conditioning is an obvious example, but many elements of urban infrastructure, home design, and personal wardrobe, for instance, are tailored to local climate.

- **Social**: A society’s norms and practices conform to its expected climate. In colder climates, certain sports are not played during the winter. In warmer ones, mise en place may be done early and late in the day, with a siesta occupying part of the afternoon.

- **Economic**: The skills people acquire and the professions they pursue will depend in part on their local climate. So, too, will their local economy’s sources of comparative advantage and the types of industries that develop. Agriculture and tourism are obvious examples of this effect, but transportation and construction are influenced as well.

Society will not make any of these adaptations in response to more day-to-day or even year-to-year variations in temperature in the way that it would adapt to decades-long climate shifts, because adaptations cost money and take time. An adaptation may represent a cost-effective response to a larger shift in underlying climate but offer very little return on investment if implemented in response to a small shift or in response to impermanent fluctuations.

This crucial point can be understood by a couple of simple examples. The failure to install an air conditioner for a year with one extra 90°F day does not mean that air conditioners will not be installed in the face of 40 extra 90°F days. Adhering to a standard roadway for outdoor jobs when the average temperature shifts from 82.1°F to 82.3°F does not rule out adjusting the workday, should the average reach 92.3°F.

Even while adaptations are immediately cost-effective, they may nevertheless be gradual. Social norms, economic configurations, and technologies emerge over time. Even if temperature fluctuations are enormous in magnitude, adaptations will be impossible where their implementation period is longer than that for which the condition lasts. The people who live in a location where the temperature swings annually by 10°F around an 85°F average may wish that it could behave like a 75°F location one year and a 90°F location the next, but this is not plausible. It will instead adapt to the behaviors, and technologies, optimal for an 85°F average with high variability. But if the underlying average shifts from 85°F to 90°F, a very different range of adaptations becomes likely.

As a result, responses designed to small-scale, short-term temperature changes cannot be automatically extrapolated to the larger-scale, long-term ones.

- **Bhulai et al.** also cites Barro and Gordon’s calculation of extreme-temperature deaths. But rather than focus on projecting deaths from extreme temperature in the future, Barro and Gordon demonstrate the extraordinary reduction in such deaths in the past. Barro and Gordon found that the lethality of temperatures above 90°F fell by 80% from the first to the second half of the 20th century, thanks primarily to the adoption of residential air-conditioning. This trend continued even within the second half of the 20th century, with the mortality effect falling by half from the 1960s-70s period to the 1980-2004 period.

The researchers concluded that air-conditioning "has positioned the United States to be well adapted to the high-temperature-related mortality impacts of climate change." Applying the Deechiho-Greenstone estimate of 42.3 additional >90°F days by 2100, they estimated that climate change could cause roughly 60,000 additional deaths in 2100 at the 1060 level of air-conditioner adoption. But at the 2004 level of air-conditioner adoption, the null hypothesis that additional 80°F-89°F and >90°F days would have no impact on mortality cannot be rejected. Or, to put this in plain English: additional extremely hot days could mean zero additional heat deaths.
Eliminating the extreme-heat estimate from Deschênes-Greenstone, or even reducing it to the statistically insignificant estimate provided in Barcon, raises another possibility: climate change could reduce extreme-temperature mortality. Deschênes-Greenstone estimated nearly 60,000 cold-related deaths avoided (specifically, a 2.9% reduction in the mortality rate), offset by twice as large an increase in heat-related deaths (a 5.8% increase in the mortality rate). Yet with Barcon’s lower estimate of heat-related costs (only a 1.5% increase in the mortality rate by the 1990–2004 period), the cold-related benefits would dominate. Climate change would reduce mortality by roughly 28,000 lives annually (see Figure 3).

Rhodium acknowledges Barcon’s finding but declines to employ it, instead combining the Deschênes-Greenstone and Barcon analyses in a way that projects a substantial increase in mortality, while deferring discussion of adaptation to a separate chapter and excluding it from the main cost estimates. If Rhodium had used the extreme-temperature mortality decrease that Barcon’s adaptation finding implies, rather than forecasting a mortality increase, its total climate-cost estimate would fall by more than 90%.

Some studies have claimed that a warmer climate will lead to declines in labor productivity and hours worked. Rhodium and EPA both rely on one of these studies, Zevin-Neidel, to estimate the effects of climate change on labor. Zevin-Neidel used an approach similar to that of Deschênes-Greenstone: it recorded the maximum daily temperature in every U.S. county on every day from 2004 to 2006, grouped the temperatures into five-degree increments, and compared them with data on time spent working from the Bureau of Labor Statistics 2005–06 American Time Use Survey, in which individuals record their activities over a 24-hour period.

Zevin-Neidel found no statistically significant effect of temperatures on overall hours worked, even for days with temperatures above 100°F, which, they wrote, "suggests that, consistent with recent findings, time allocated to labor on hot is not responsive to changes in temperature." But the researchers looked separately at industries that the National Institute for Occupational Safety and Health considers “heat-exposed”: agriculture, forestry, fishing, hunting, construction, mining, transportation, utilities, and manufacturing. Within this “high-risk” subset, very high temperatures did
appears to reduce hours worked—by up to almost one hour per day for temperatures over 90°F. Both Rhodium and EPA apply this finding to the expected increase in very hot days to estimate the total loss in economic activity by 2100.

Zievin-Neidell provided a plausible test to rule out potential adaptation: it found a similar response to very hot days in both warm and cold counties. This would suggest that the response to a hot day may not change with climate warming. This does not rule out possible technological innovation in the future (such as cooling vests) or sectoral economic change (the share of workers conducting manual labor in 2000 may be much lower or such economic sectors may relocate in time or place). But its finding of decreased work in high temperatures is the most plausible of the results reviewed here and also makes intuitive sense: reduced work on hot days is itself an adaptive strategy—the sort of behavior that keeps workers safe.

Nevertheless, Zievin-Neidell illustrates a second shortcoming of temperature studies: a lack of context. A model can forecast only what it is designed to forecast; here, the marginal effect of extreme heat on hours worked—but not the absolute number of hours worked or labor productivity itself. Zievin-Neidell does find that workers in high-risk industries work less on days of extreme heat—but it also reports that those in the hottest third of American counties work more on a typical summer day than those in the coolest third of counties (see Figure 4).45 Hot weather reduces hours worked on the days when it occurs, but hotter climates within the U.S. do not necessarily experience fewer hours worked overall.

Why might this be? Perhaps heat-sensitive workers in hotter climates compensate for the need to work less on very hot days by working a slightly longer day on other days.46 Regardless, the study’s findings do not support a conclusion that a shift toward a warmer climate with more hot days will mean lower economic output.

Climate Change and Air Quality

Higher temperatures can also interact with other environmental processes to change the atmospheric concentration of pollutants, even if pollutant emission rates do not change. For instance, ground-level ozone (“smog”) gets worse on hot days. EPA tried to quantify these air-quality effects based on another study, Garcia-Mendez.47 Garcia-Mendez combined existing air-quality and climate-change models to forecast changes in atmospheric concentrations of ground-level ozone and particulate matter by 2100 if emissions remained constant but temperatures increased. It found that while concentrations would increase in some places and decrease in others, the average U.S. resident would be exposed to slightly increased levels of pollution: an increase of 0.2 parts per billion for ozone and 1.5 μg m⁻³ for particulate matter (or, respectively, 2.6 parts per billion and 1.2 μg m⁻³ greater than an alternative scenario in which climate change is aggressively fought).

Garcia-Mendez applied existing EPA formulas to these pollution increases to estimate that unchecked global warming would cost 77,000 lives per year in 2100, relative to an alternative scenario with aggressive action against global warming.48 EPA assigned a value of $90 billion per year to those lives. The number of deaths seems alarming but appears much less consequential when placed in the context of present-day experience.

Here’s why. The paper estimated that unchecked climate change would increase ozone levels by 2.6 parts per billion and particulate-matter levels by 1.2 μg m⁻³, over the alternative scenario.49 But those concentrations...
have fallen since 2000, from 82 and 13.4, respectively. In 2009 alone, particulate matter fell by an amount almost equal to the increase that climate change would cause over the century. In most of the years from 2000 to 2015, ozone levels fluctuated by more than the climate-induced effect over a century. Put another way, the forecasted effect of climate change on air pollution is to return atmospheric quality from 2015 to 2011 levels (see Figure 5).26

Garri-Mendoza also implicitly assumes that recent decades’ extraordinary pollution reductions will cease for the rest of the century and that no new technologies will reduce human exposure to pollution or its danger to health. In fact, ozone and particulate matter levels for most of the country are already below thresholds that EPA deems safe, and those levels will almost certainly be far lower by century’s end. In the context of a century of economic, social, technological, and environmental change, the identified impact of climate change on air pollution is barely noise. Yet it represents the majority of costs of all climate effects that EPA reports—$920 billion of $1.9 trillion.27

Purely statistical arguments cannot be evaluated without a real-world context. If climate change were projected to create unprecedented conditions, there might be no alternative to reliance on abstract statistical models. But where forecasted conditions for 2100 resemble past or present experiences, those experiences and likely technological advances should be the starting point (not the end point) for discussion.

Climate Change and GDP: Is the World Headed Toward the Mongolian Century?

Several other reports have garnered widespread media attention for temperature-study-based estimates of climate change’s impact on GDP. For example, a set of authors nearly identical to those responsible for Rhodium published a study in Science in June 2017. That study, Hsiang, drew on the same studies as Rhodium to generate detailed, county-level estimates of climate change’s impact on GDP. As reported that “according to EPA officials, this study [Hsiang] represents a major advance in the field.”28 Hsiang estimates a nationwide cost by the year 2100 of 1.5%–4.6% of GDP but a cost exceeding 20% in some regions. Roughly 80% of the total cost derives from extreme heat deaths and lost working time.29 Oddly, Hsiang reports costs as a share of GDP but uses GDP in the year 2011 as the denominator.30 Thus, on top of the aforementioned failures to account for adaptation, it also imagines an economy of 2100 no larger than today’s.

Most significantly, whereas Rhodium and EPA estimate climate costs by summing the damage caused by various effects, another paper—Burke—created enor-
If global warming makes heat currently regarded as extreme more frequent and less surprising, then temperate cities will almost certainly make adaptations to function better in heat, much as people moving to cities in warmer climates have already done.
mass cost estimates by pushing the temperature-study methodology even further. Burke is not reviewed in GAO but is coauthored by the lead author of Rhodium and Science. Burke provides the most abstract analysis of any surveyed here. After a few introductory references to studies of agricultural and labor productivity (including Zivin-Snedell), it abandon’s consideration of global warming’s effect on anything more concrete than national GDP. Burke compares year-to-year variations in a country’s average temperature with variations in those same years in economic growth, controlling for associated changes in precipitation. It found that in countries with average temperatures below 13°C (55°F), about the average temperature of Baltimore, Milan, Beijing, or Wellington, growth was better in warm years; countries with higher average temperatures saw better growth in cool years.

Burke theorizes that these short-term fluctuations exhibit a universal effect of temperature on growth — every country would see its maximum growth (determined by non- meteorological factors) at a 13°C average temperature. Burke constructs a model in which every country’s baseline temperature is its average during 1960–2010 and its baseline rate of economic growth is forecasted by the Shared Socioeconomic Pathway (SSP, a widely used set of national GDP predictions that assumes a stable climate). The difference between the baseline temperature and temperature forecasted in some future year by a climate model provides the variation used to predict how growth in that year will vary from the SSP forecast.

Let’s say that a country’s gradual warming raises its temperature from, for example, 13°C during 1960–2010, to 19°C in 2050. The model attempts to predict the effect on economic growth of a 15°C country experiencing a sudden 19°C year. But the economic performance of other countries with a present-day 19°C average is ignored. Burke builds a modified set of SSP growth forecasts that accounts for the effect of warmer temperatures on every country in every year, and concludes that global warming will reduce per-capita gross world product (GWP) by 25% by 2100.

As in Mills, projecting each location’s response to a century-long temperature change on the basis of how locations reacted to small variations from their own averages in the past produces extremely dubious, if not preposterous, results. Burke’s model takes normal economic growth in cold or hot countries as a sign of economic specialization to a local climate but of often stupendous underlying growth potential that the local climate suppresses. For instance, according to the Burke model, if Cambodia (average temperature 28°C (82°F)) were blessed with an American climate (14°C (57°F)) for the 21st century, it would achieve GDP per capita approaching $300 million by century’s end. By contrast, Burke uses baseline GDP per capita in 2010 of $36,000 for the U.S. and $400 for Cambodia. But if the U.S. were forced to cope with Cambodia’s climate, its per-capita GDP would fall by more than half every decade. If Cambodia and the U.S. shared a climate of 21°C (69°F), similar to that of Houston, Tel Aviv, or Brisbane, then Cambodia’s purportedly superior non-meteorological characteristics would send its per-capita income skyrocketing past the American level by 2040. The effects of predicted global warming are less dramatic but likewise implausible. For instance, Burke forecasts that Mongolia, whose per-capita income of $881 made it the 188th wealthiest country in 2010, will leap to seventh in 2100, with a per-capita income of $980,000—more than four times America’s projected per-capita income of $90,000. Iceland achieves a per-capita income of $1.5 million, more than twice that of any other country besides Finland ($860,000), with annual economic growth above 5% and accelerating (see Figure 6). Canada’s economy becomes the world’s second-largest (behind only the U.S.), nearly seven times larger than China’s.

Conversely, Burke expects India to be the world’s poorest country in 2100, with per-capita income no higher than in 2050 and declining at almost 4% per year. It expects Israel, the country that made the desert bloom (and found itself with a water surplus during the intense drought that some consider a catalyst for Syria’s civil war), to have a per-capita income in 2100 similar to its 2010 level and declining at more than 3% per year.

In a blog post, coauthor Marshall Burke addressed critics of the paper, whom he paraphrases as saying, “These results just don’t pass the ‘sniff test,’” or, “Your impacts are too big, and they just can’t be true.”

As far as I can tell, ‘this doesn’t pass the sniff test’ is just a snarky way of saying, ‘this disagrees strongly with what I thought I knew about the world, and I am uninterested in updating that view.’ . . . So, yes, the future world might look different than the current world. But saying that is a cop-out, unless you can tell a convincing story as to exactly why the future is going to look so different than the past. Our guess is that you are going to have a hard time telling that story with an appeal to the historical record.”
Perhaps we should accept that a 25% loss in global warming may be politically feasible within the next few years, and that this may be the key to stabilizing the planet and preventing catastrophic outcomes. A 25% reduction in emissions could make a significant difference in slowing global warming and addressing climate change.

To achieve this, concerted efforts must be made at the national and international levels. Policies designed to reduce greenhouse gas emissions should be enacted, and existing frameworks, such as the Paris Agreement, should be strengthened and expanded. Public awareness campaigns and education programs can also play a crucial role in raising public consciousness about the need for action on climate change.

In addition to these measures, technological advancements and innovation could be key drivers of change. The development of cleaner energy sources, such as wind and solar power, could help to reduce reliance on fossil fuels and mitigate the impacts of climate change. Similarly, advancements in carbon capture and storage technologies could provide a means of reducing emissions from existing power plants and industrial processes.

Ultimately, achieving a 25% reduction in global warming will require a coordinated and comprehensive approach, involving governments, businesses, and individuals. By working together and taking decisive action, we can make a meaningful impact on slowing the rate of climate change and safeguarding the future of our planet.
statistical uncertainty surrounded the overall estimate of a 2.3% loss in per-capita income that the study reported a 29% chance that temperature increases in 2100 would raise global wealth.44 The 95% confidence interval, traditionally used to determine a finding’s statistical significance, spans a range of estimates from a more than 20% loss of per-capita income to a more than 50% gain.45

Similarly, Deschênes-Greenstone reported a statistically significant relationship between extremely hot days and mortality nationwide, but when it considered nine regions separately, it found a statistically significant relationship in only three.46 Two other regions, the Middle Atlantic (NJ, NY, PA) and the West South Central (AR, LA, OK, TX), exhibited an insignificant inverse relationship: more hot days appeared correlated with fewer deaths. Still, multiplying the best nationwide estimate by an increase from one to 44 annual days of >90°F heat produced, in Deschênes-Greenstone, a massive death toll.47

Many recent temperature-study-based estimates of climate-change cost overestimate models constructed from small short-term effects and make untenable no-adaptation assumptions; the large harms that they forecast often represent aggregations of implausible local predictions. When results do account for adaptation and are presented in context, they point toward low and manageable climate-related costs. The odds are vanishingly small that the world is headed toward the Mongolian Century.

Conclusion

The critique of temperature studies in this paper does not mean that researchers should abandon estimates of the future costs of human-caused climate change. There is every reason for policymakers to continue to carefully consider legitimate cost estimates. So, too, researchers should continue to study the concrete effects of absolute changes in temperature and the nature of associated adaptation, as these findings help to identify which climate-related threats are the most severe and which adaptations may require changes in public policy.

For example, continued research on sea-level changes and their implications for coastal development will be invaluable to responsible public policy in the decades to come. In Deschênes-Greenstone, alongside the finding that air-conditioning can mitigate heat-related mortality, the authors also study the effects of extreme temperatures on energy consumption and show that it (and the associated cost) rises significantly. Just because adaptation is desirable and likely to occur does not make it free.

But correlation-based temperature-impact studies that produce very high estimates of the economic and social costs of projected climate change—meanwhile ignoring or downplaying the possibility of adaptation and obscuring the inaccuracy of underlying estimates—are distinctly unhelpful.
Endnotes
Connor Hanx, a policy analyst at the Manhattan Institute, provided research assistance for this report.


3. GAO, p. 3.

4. Would provide alternative measures for heat-related mortality and coastal impacts. The totals here use the methodologies that produced the highest cost estimates. Rhodium figures, as reported by GAO, use consistent 2017 dollars. Figures here are updated to 2014 dollars.

5. EPA estimates $16 billion-$34 billion in emergency system costs reported for 2003, if it provided no estimate for 2010.


10. Mills, Table 2.

11. E-mail correspondence with David Mills, Jan. 17, 2019. See EPA, "Extreme Temperatures," n. 20, for discussion of EPA's constraint in the Mills model to additional cities.


13. Most temperature studies, including those discussed here, acknowledge their failure to account for adaptation or caution that their conclusions will not hold if adaptation occurs. Nevertheless, their no-adaptation findings are reported as credible estimates of future climate costs.

14. Mills, Table 2.

15. Deschênes-Greenstone, Figure 2.

16. Deschênes-Greenstone, Table 1.

17. Deschênes-Greenstone, Table 5.

18. The causality of climate was Karen Dix, Olivier Deschênes, Michael Greenstone, and Joseph S. Shughart. The version of Banerji cited in this full report is the paper published in the final form after the release of Rhodium. Rhodium cites a substantially comparable version of the paper released in Jan. 2013 in an NBER working paper.

19. Banerji, Figure 3.

20. Deschênes-Greenstone presents its final mortality estimates for both increased heat-related deaths and discounted cold-related deaths in Table 5. Look, 10-10. The net effect, an increase of 16,000 deaths, translated to a 1.2% increase in the mortality rate of 45.

21. The suggestion to translate the Banerji estimate into terms comparable with the Deschênes-Greenstone estimate, as well as the technique for doing so, comes from one of the study's authors (see e-mail correspondence with Oliver Deschênes, Dec. 25, 2017). The Banerji point estimate of 1.323 (for 1990-2004) is divided by the 2-month mean temperature (to account for the two-month mean temperature variance) and multiplied by 182 to give the percentage change in mortality per °C "of influence and then translated by 16.2 additional deaths to give the mortality increase equivalent to those discussed in deschênes-Greenstone. The Rhodium author's use similar processes to convert the Banerji estimate into terms comparable with Deschênes-Greenstone: see Heising, Supplemental Material, 85. Greenstone estimates in the deschênes-Greenstone and Banerji methodologies and data sets, combining their outputs provides only a rough estimate. The approach we used here to illustrate the large effect of accounting for adaptation by the authors of Heising: a full analysis would be expected to produce a new point estimate.

22. Rhodium, p. 65, the discussion of adaptation on p. 68 estimates that the effect would remain negative but reduces the magnitude by approximately half.

23. Rhodium uses a value for R of 1.75 million to yield a midpoint cost estimate of $26 billion (see p. 101). Imposing roughly 37,000 total excess fatalities, it reported 65,000 total fatalities, the benefit would be $32 billion. This would change the total estimated costs in Rhodium from $267 billion over the 1990-2010 period to $82 billion in 2010.

24. Zee-Mazzetti, Table 2.

25. The study looks for another form of adaptation called "catch up," in which workers adjust to working fewer hours on a hot day by working more hours on the mimimizable surrounding days, and finds no such effect.

26. Rhodium discusses at quality but does not provide damage estimates.

27. Garcia-Armendariz, Table 3.

28. Mills describes the effect of climate change on population-weighted concentrations, the underlying EPA data presented here on the nationwide levels between 2000 and 2015 (i.e., not population-weighted).


30. EPA, p. 79-79; see also GAO, p. 22.

31. GAO, p. 55.

32. Heising, Figure 5.

For comparison, this estimate is an order of magnitude larger than the cost of 1%–4% of GDP estimated by the Obama administration in its “Social Cost of Carbon” analysis, see Figure 1 in “Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis—Under Executive Order 13563,” Interagency Working Group on Social Cost of Carbon, Feb. 2010.

My calculations are based on coefficients reported in Burke, Extended Data Table 1, and baseline country values are provided by the authors at https://web.stanford.edu/~m-burke/Climate/data.html, see “Projected per capita GDP without climate change.” Calculations exclude negligible precipitation effects included in Burke.

The authors provide country-specific model results at https://web.stanford.edu/~m-burke/Climate/data.html, see “Projected per capita GDP with climate change.”


In his Oct. 26 blog post, Burke acknowledges, “Whether people respond differently to short- versus long-run changes in temperature is an empirical question, and one that is often tricky to get a handle on in the data.” He directs readers to a working paper dated Jan. 14, 2015 that he co-authored, which finds that U.S. corn and soybean farmers have made only minimal, successful adaptations to global warming to date. This paper was eventually published, see Marshall Burke and Kyeom Kim, “Adaptation to Climate Change: Evidence from US Agriculture,” American Economic Journal: Economic Policy 8, no. 3 (Aug. 2016): 100–45. But Burke acknowledges that such findings may not apply generally. He does not address the quality or reliability of the Burke country-level estimates, instead concluding, “But again, just clothing that responses derived from studying ‘weather’ are a data guide to understanding ‘climate’ is not that satisfactory. Show us how long-run responses are going to be different.”

Burke, Fig 1h.

For the 23% figure, see Burke, p. 20, for the 29% figure, see p. 238 and Extended Data Table 3.

Burke, Fig 1a.

Deschenes-Greenstone, Table 3.

The study reports a lower net effect of climate change because the increase in deaths from extreme heat is partially offset by a reduction in deaths from extreme cold.
Abstract

Prominent recent studies that forecast the cost of human-caused climate change rely on statistical analyses of the effects of temperature variation. These correlation-based, temperature-impact studies start with present-day relationships between temperatures and outcomes such as mortality or economic growth. They extrapolate from those relationships a proportionally larger response to long-term projected climate warming and assign dollar values to the very large impacts that appear to emerge.

This paper examines a set of such studies that the U.S. Environmental Protection Agency and the U.S. Government Accountability Office have used to estimate the costs of human-caused climate change for the U.S. by the end of the 21st century. The costs include deaths from extreme heat, lost hours of work from extreme heat, and deaths from heat-caused air pollution. The paper also examines another study, published in Nature, that projects the effect of human-caused climate change on global economic production.

Key Findings

1. Temperature studies do not offer useful projections of deaths and lost hours of work for extreme heat, or deaths due to heat-caused air pollution, in the U.S. The projection of lower global economic output due to projected human-caused climate change is also flawed.

2. The crucial (though not the only) flaw of temperature studies is that they neglect human adaptations to a changing climate. Such adaptations have already been made by industrial societies expanding into warm regions such as the American South and Southwest. The temporary effects of temperature variations—such as an unusual hot spell—cannot be equated with a long-term change in temperature patterns. For example, the failure of people to install air conditioners in a year with one extra 90°F day does not mean that they won’t do so in the face of 40 extra 90°F days.

3. Properly understood, temperature studies do not offer useful predictions of the future costs of projected human-caused climate change.
Chairman YARMUTH. Thank you very much Mr. Cass. We will now begin our question-and-answer period. And Mr. Johnson and I are going to defer our questioning until the end of the hearing.

So I will now recognize the gentleman from California, Mr. Peters, for five minutes.

Mr. PETERS. Thank you, Mr. Chairman. I want to observe that something people may not see on TV, that this place is packed. I see rows of people here, listening to this testimony. And I judge that maybe three or four of them are over 30 years old. This is something that is, obviously, of great importance to people in this building. This is as packed as the Mueller hearings might be in the Judiciary Committee. Not as many members, but the crowd is certainly interested.

And I also want to respond to my colleague, Mr. Johnson, about the Green New Deal. I don’t support the Green New Deal for two reasons. One is a policy reason. It contains economic strategies and things like guaranteed jobs that are extraneous to climate action. And I think—with which I disagree. So, in fact, I think most of the Members of this Committee on the Democratic side have not sponsored the Green New Deal, probably—maybe for that reason, but for the other reason that is even more fundamental—is that it is divisive.

I feel like we are—that people have explained some pretty overwhelming impacts of climate change. Even Mr. Cass suggests they may be overstated, but no one denies that these are issues before us. My mom always told me to pray for the best, but plan for the worst. So, with respect to you, I am concerned about what Dr. Hayhoe said. And we need, I think, to make radical change. But I think, to do that, to get radical results, we are going to have to moderate our politics.

The first thing I heard in here was about the Green New Deal and the cost of it. And I think, you know, it is a fact that most of us haven’t endorsed it for that reason. I also heard from my own side of the aisle how Republicans are to blame for this, and I don’t know whether that is true or not, but I am not—I did litigation, and that is not what I am here for. I think we are here to solve problems. And I think we have got a pretty big one in front of us.

So I have suggested—I have taken a different approach I just want to call to your attention, to each of the four of you, which is I was thinking what—you know, what—we have been working on this for a while. I have been in Congress—this is my fourth term. People have all sorts of good ideas about what to do about climate. And I decided to put them together.

So I went back and looked for all the—we have done this in conjunction with academics from Duke, and Stanford, UCSD. We have looked back at all the—we looked back at all the ideas, the bills that had been introduced in this Congress and the last Congress, and we compiled them into what we called the Climate Playbook. And for you people under 30, it is the pinned tweet on my official Twitter account.

I would ask you to look at it, but it is ways to reduce—it is ideas for reducing emissions from various sectors of the economy, including manufacturing, electricity, transportation, agriculture, promoting energy efficiency—something we can all get behind.
And everything except what Mr. Johnson said about the Green New Deal, by the way, I agreed with. Reducing pollution, increasing R&D investment, adaptation resiliency, there is all sorts of ideas out there that we can get behind today if we get our politics behind us a little bit and start to work together.

And I want to ask Ms. Hayhoe, who is kind of famous for being not just a climate scientist, but also an evangelical Christian.

So you are in circles that a lot of Democrats don’t travel in all the time, and I wanted to know if you had any ideas for me, as a Democrat, on how we might be able to engage people in really solving this problem, which is bigger than politics.

Dr. HAYHOE. Thank you. So I am an evangelical Christian, my husband is a pastor. And what I have found is that so often we think people don’t have the right values to care, and we need to figure out how to change people’s values. But through thousands of conversations that I have had with people in our faith community in Texas and beyond, I realize that we all already have those values. We all care about our families, we care about our communities, we care about people who are suffering today, poverty, hunger, and more. And those are the exact values that we need to care about a changing climate.

So it isn’t a case of emphasizing what divides us; it is, as you just said, a case of emphasizing what unites us, because that is far greater.

Mr. PETERS. I think that is well said. I think you see this—and the Evangelical environmental movement is taking this up.

And look, I used up all my time talking. But politics is about us. It is not about the world. We are here to—we are here doing politics, ostensibly, as a means to an end. And I think we ought to think about that. And I would ask my colleagues on both sides of the aisle to—let’s work together, check out these ideas that we have assembled, and see if we can’t start making real action.

I yield back.

Chairman YARMUTH. The gentleman’s time has expired. I now recognize the gentleman from Missouri, Mr. Smith.

Mr. SMITH. Thank you, Mr. Chairman. As the gentleman from California just stated, there is only standing room here, witnessing this.

I also have to point out that it is pretty unfortunate that, on this side of the Committee—that is where the Democrats sit—and you can see on this side is the Republicans. We are the ones that is here. There is five Democrat members, and they are the majority. So they may not be as nearly as interested about the issue that you all are right now. So I just think it is important to notice that.

Fifty-seven days. Fifty-seven days. This Committee has went 57 days without passing a budget. Yet this week we are doing five appropriations bills on the floor. The Democrat majority has rendered the Budget Committee useless, because we have not done our job, and we are having a hearing on climate change today, when we still need to pass a budget. There is not even a budget proposal out there for this Committee to vote on, other than a Republican budget proposal. Let’s do our job. It is 57 days.

A budget is the primary responsibility of governing, it is the only document that Congress produces that lays everything out: reve-
nues, spending, deficits, and, of course, our vision for the future. A statement of values, as Speaker Pelosi has called it. Yet after 57 days and counting, we have no statement from the House Democrats.

The reason why is clearly obvious. Free college tuition, Medicare for all, guaranteed jobs, and, of course, the $93 trillion Green New Deal. The numbers don't work. The Green New Deal that has been discussed and Medicare for all, just two priorities of the House Democrats, would together cost $20 trillion more than the net worth of every American household, $20 trillion more than the compiled net worth of every American household, over 320 million Americans.

Knowing this wish list only scratches the surface, I have no confidence Democrats on this Committee can make serious decisions about our federal budget. And they don't seem to have any, either. So instead, today we are having a hearing on climate change.

And what is their proposal to address climate change? The previous-mentioned Green New Deal, which more than half of the Democrats on this Committee have sponsored. More than half. That is why it should be topic of conversation of this Committee. A plan that would cost every American household $60,000 a year. Every American household, $60,000 a year, while not fulfilling its primary objective, which is reducing global carbon emissions.

While the plan may fail in its primary objective, it would be very effective in others: mainly, in destroying American agriculture as we know it today. If you don't believe it, that it is an objective, look no further than the infamous fact sheet.

No one cares more about their land than American farmers and ranchers. Thanks to their innovative solutions, they do numerous things to protect the soil, the water, the habitat. Look at the Missouri soil and water conservation. We do it right in Missouri.

Democrats say they want to improve the environment. But if they accept that premise, it is hard to understand why they haven't brought the great trade agreement President Trump has negotiated to the floor, an agreement that would bring back jobs, increase purchases of U.S. agriculture goods, and yes, improve the environment. Thanks to President Trump, our most recent trade agreement is the most comprehensive—has the most comprehensive environmental obligations of any previous U.S. trade agreement in history, which also would provide Canada and Mexico to up their standards in protecting our environment.

Mr. Chairman, I see my time is yield—my time has expired. I yield back.

Chairman YARMUTH. I thank the gentleman. And I would note that, while you criticized Democrats for not being interested in this topic, you didn't even address climate change in your five minutes. But we will——

Mr. SMITH. I said, “The Green New Deal.”

Chairman YARMUTH. That is not climate change; that is a piece of legislation.

[Laughter.]

Chairman YARMUTH. I yield—I now yield five minutes to the gentlelady from the state of Washington, Ms. Jayapal.
Ms. JAYAPAL. Thank you, Mr. Chairman, and thank you for holding this very important hearing.

And I would just say, with all due respect to my very good friend across the aisle, if you really want to know which party cares about climate change, let’s look at which party pulled us out of the Paris accord. Let’s look at which party, while they were in the majority in the last cycle, rolled back all of our environmental protections around clean air and clean water. Let’s look at which party is putting in charge of major agencies people who literally are lobbyists for the coal industry.

And I want to bring this up in the context of—and I—by the way, I am a proud supporter of the Green New Deal. It is crazy to talk about it in terms of a cost, because what it is is a vision. It is a vision for an absolutely critical issue, one of the top issues in this country and around the world. And we need to have a big vision that matches the scale of the crisis.

Last week the House Intelligence Committee held a hearing on the national security implications of climate change. And something very odd happened at that hearing: although three witnesses testified, only two submitted written testimony. That is because the White House took the unusual step of refusing to approve the written testimony of a top intelligence analyst at the State Department, Dr. Rod Schoonover, because it contained information that did not match the Trump Administration’s views on climate change.

This weekend the New York Times obtained a copy of his original testimony and a copy of his testimony with track changes. I have got the whole document here from Dr. William Happer, a senior adviser in the Trump Administration, who works with the National Security Council. He is also a climate science denier. And since we have a panel of climate experts here with us today, I thought I would take the opportunity for us to look at Dr. Schoonover’s testimony and determine whether his positions are in line with the science, not whether they are in line with the opinion of the Trump Administration.

And so let me start with you, Dr. Hayhoe. You are a top climate scientist and lead author of multiple volumes of the National Climate Assessment. Is Dr. Schoonover correct in his written testimony when he says that, “The earth’s climate is unequivocally undergoing a long-term warming trend”?

Dr. HAYHOE. Yes, chapter one of volume one of NCA concludes that global climate continues to change rapidly, compared to the pace of natural variations in climate that have occurred throughout earth’s history.

Ms. JAYAPAL. That was a comment that was taken out. And how about when he says 18 of the last 20 years—this is a quote—have been the warmest on record, and the last five years have been the warmest five according to NASA’s Goddard Institute of Space Studies?

Dr. HAYHOE. Yes. That information is available, and anyone can see it for themselves, in chapter two of volume two, which I served as lead author.
Ms. JAYAPAL. So once again, that was something that, in the written comments, it was completely taken out and denied as not being science.

And how about this one? Ocean waters are also acidifying from the absorption of atmospheric carbon dioxide. Is that a true statement?

Dr. HAYHOE. Yes. That is summarized in chapter 13 of volume one, which was called “Ocean Acidification.”

Ms. JAYAPAL. So again, very important facts that were taken out by Mr. Happer.

Mr. Chairman, I would like to enter a clean copy of Mr. Schoonover’s—Dr. Schoonover’s testimony into the record today, since it wasn’t entered into the House Intelligence record.

And I would also like to enter a copy of the version with Dr. Happer’s track changes, in which all three of these facts were deleted.

Chairman YARMUTH. Without objection, so ordered.

[The information follows:]
Dr. Rod Schoonover  
Senior Analyst  
Bureau of Intelligence and Research  
Department of State  

Hearing on  
The National Security Implications of Climate Change  

Before the  
Permanent Select Committee on Intelligence  
U.S. House of Representatives  

June 5, 2019
Chairman Schiff, Ranking Member Nunes, and distinguished members of the Committee, thank you for inviting me to speak with you today on the national security implications of climate change.

As a U.S. intelligence officer in the Department of State Bureau of Intelligence and Research it is my job to provide clear, objective, and independent analysis to policymakers to advance U.S. national security objectives. As a scientist in the intelligence community (IC), I blend insights derived from peer-reviewed journal articles and other scientific reports with information gathered from daily intelligence reporting to provide science-informed national security analysis. My understanding of this and other issues is deepened by the cadre of talented and dedicated officers in the IC, many with technical expertise, who quietly serve U.S. interests. This Committee is already aware that the IC does not advocate for any particular set of policies, including those that address climate change.

The Bottom Line

Fundamental characteristics of the global climate are moving outside the bounds experienced in modern history and there is uncertainty on how some aspects of the climate will evolve. Given the complex social and political contexts in which a multitude of changes are occurring, however, we can expect new and compounded stresses on people and societies around the world, many with outcomes important for national security.

Climate change will have wide-ranging implications for U.S. national security over the next 20 years through global perturbations, increased risk of political instability, heightened tensions between countries for resources, a growing number of climate-linked humanitarian crises, emergent geostrategic competitive domains, and adverse effects on militaries. Increasingly probable amalgamations of these security concerns are especially worrisome. Climate change alone is unlikely to trigger state failure in the next few decades but it will affect factors that contribute to conflict, such as access to natural resources. People will increasingly decide to move because of deteriorating conditions, both within nations and into countries that are more prosperous. Perhaps most importantly, the rapidity of concurrent and compounded changes to Earth’s systems, from human and natural causes, heightens the risk for unwelcome and possibly severe climate-linked surprises.

Framework for Analysis

The IC’s task with respect to climate change is to inform policymakers of the myriad risks and uncertainties that may lie ahead, rather than trying to predict the future. We have therefore examined a wide range of climate change effects, including those currently believed to have low probability, particularly if the ramifications could be highly impactful. The IC focuses on security considerations outside the United States, so we do not address the direct effects of climate change on the U.S. homeland. We expect, however, that many judgements could nonetheless apply to the United States.
For this analysis, we consider an event a national security concern when it:
- Produces a noticeable, even if temporary, degradation of one of the elements of U.S. national power: geopolitical, military, economic, informational, social cohesion
- Indirectly influences the United States, through a strategically important ally or partner
- Causes adverse effects that indirectly consume U.S. resources

Analyzing the national security implications of climate change generally requires tracing a logic trail from climate stressor to climate-linked event to societal stress to security concern, an endeavor complicated by climate conditions being intertwined in a complex of social, political, and biophysical conditions (Figure 1). Enumerating the large number of other important contributing factors is beyond the scope of this document, but illustrative examples include consumption patterns, demographics, environmental degradation, existing social and political conditions, land-use changes, emerging technologies, governance, and the tendency for populations to concentrate in climate-vulnerable locations. Changing climate conditions, in combination with other stressors, almost certainly will increasingly threaten national security over the next few decades.

**Figure 1: Schematic Links Between Climate Change and National Security**

![Diagram](image)

*Source: Adapted from Climate and Social Stress, National Research Council 2013. Many links involve causal relationships in both directions, and some links are more important than others. Outcomes from human and societal stress are highly dependent on a given population’s exposure, vulnerability to harm, and ability to cope, respond, or recover from a climate-linked event.*

**Scientific Baseline**

The IC does not develop climate science; we instead rely on findings from outside sources. We prefer to use U.S. Government sources, such as NASA, NOAA, USGS, and the U.S. Global Change Research Program. In addition, U.S. scientific institutions such as the National Academies of Sciences, Engineering, and Medicine provide valuable consensus reports. We also utilize information and analysis from many other domestic and international sources, particularly the Intergovernmental Panel on Climate Change (IPCC) and peer-reviewed journals.
The Earth's climate is unequivocally undergoing a long-term warming trend as established by decades of scientific measurements from multiple, independent lines of evidence (Figure 2). Eighteen of the last 20 years have been the warmest on record and the last five years have been the warmest five, according to NASA's Goddard Institute for Space Studies, a finding echoed by other countries' meteorological agencies. Extreme high-temperature events are increasing across the globe as the distribution of observed temperatures skews towards higher values and the predictability of temperatures is declining. Temperatures are rising faster over landmasses, particularly near the poles, than open oceans, and global records indicated temperatures have been rising at all depths of the ocean, which absorbs over 90% of heat trapped within the Earth's climate. Ocean waters are also acidifying from the absorption of atmospheric carbon dioxide.

Looking ahead, global average surface temperatures will continue to increase over the next several decades, due largely to past emissions of long-lived greenhouse gases such as carbon dioxide. Beyond a few decades, however, additional temperature increases will critically depend on the cumulative atmospheric concentrations of greenhouse gases. Since ocean warming considerably lags that of the atmosphere, ocean temperatures will increase well into the future.
Rising temperatures in turn drive changes in a vast number of Earth system processes, particularly in the atmosphere, ocean, freshwater, soil, ice masses, permafrost, and organisms comprising the biosphere. The Earth’s complexity complicates a detailed understanding of how these myriad temperature-dependent processes evolve and interact over time and space, but scientists have elucidated trends for an important set of climate-linked phenomena including and beyond temperature (Figure 3). Over time, ongoing temperature increases will likely expose populations to a greater number of concurrent climate-linked events. There will also be other unexpected—and potentially disruptive—climate-linked events currently uncharacterized by the scientific community.

**Figure 3: IPCC-Projected Trends in Selected Climate-Linked Phenomena (2050-2100)**

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Change</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global mean surface temperature</td>
<td>🔺</td>
<td>HIGH</td>
</tr>
<tr>
<td>Global mean sea level</td>
<td>🔺</td>
<td>HIGH</td>
</tr>
<tr>
<td>Arctic sea ice cover</td>
<td>🔺</td>
<td>HIGH</td>
</tr>
<tr>
<td>Hot days and nights over land (warmth, frequency)</td>
<td>🔺</td>
<td>HIGH</td>
</tr>
<tr>
<td>Cold days and nights over land (warmth, frequency)</td>
<td>🔺</td>
<td>HIGH</td>
</tr>
<tr>
<td>Extreme high sea level (incidence, magnitude)</td>
<td>🔺</td>
<td>HIGH</td>
</tr>
<tr>
<td>Heatwaves and warm spells over land (frequency, duration)</td>
<td>🔺</td>
<td>HIGH</td>
</tr>
<tr>
<td>Heavy precipitation events</td>
<td>🔺</td>
<td>HIGH</td>
</tr>
<tr>
<td>Droughts (intensity, duration)</td>
<td>🔺</td>
<td>HIGH</td>
</tr>
<tr>
<td>Tropical cyclones in North Atlantic and Western North Pacific basins</td>
<td>🔺</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>(intensity, frequency)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global mean precipitation</td>
<td>🔺</td>
<td>MEDIUM</td>
</tr>
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<td>Contrast between wet and dry regions</td>
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<tr>
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<td>MEDIUM</td>
</tr>
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<td>Storm tracks (poleward shift)</td>
<td>🔺</td>
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<td>🔺</td>
<td>HIGH</td>
</tr>
<tr>
<td>Animal and plant species distribution (poleward and upward in altitude)</td>
<td>🔺</td>
<td>HIGH</td>
</tr>
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<td>Timing of ecological spring events (leafing, greening, migration, etc.)</td>
<td>🔺</td>
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</tr>
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<td>🔺</td>
<td>HIGH</td>
</tr>
</tbody>
</table>

Source: Adapted from Intergovernmental Panel on Climate Change (IPCC), WG II, AR5, 2014. Projections assume that the average global temperature increase will exceed 2°C (3.6°F). The confidence statement reflects the IPCC’s qualitative assessment of the robustness of evidence and agreement between different lines of evidence: "high" indicates very high or high confidence while "medium" denotes medium confidence. Phenomena with no clear trend or with significant regional variation are not shown. The IPCC employs the 2050-2100 timeframe to establish general trends; the national security window is usually shorter and on the order of days to a few decades.

Key:
- 🔺: Increasing overall
- 🔺: Decreasing overall
- 🔺: More regions increasing than decreasing
Extreme weather and climate events are a major risk for all societies. They are caused by the rare occurrence of extreme values of certain meteorological variables, such as high and low temperatures (heat and cold waves), increased and reduced amounts of precipitation (floods and droughts), and high wind speeds (storms). Such events may occur at different rates, with different intensities, or at different locations compared to historical patterns, any of which may be disruptive. Over the last 10 years, the IC has deepened its appreciation of the significance of extreme weather events to national security. Most significantly, based on the science, we have come to appreciate that such events are a more near-term risk than previously assessed.

For classes of extreme events that increase in frequency of occurrence, we expect that the distribution of future extreme events in geographical location and time will be increasingly important in terms of potential for harm. Multiple extreme events of modest intensity that are clustered, compounded, or sequential may be more damaging or disruptive than single events that are more powerful. We also recognize the potential for analogous climate-linked extreme events in the biosphere, such as a mass die-off of an economically important species or sudden emergence of a destructive pest. Such events are not well characterized in the academic literature but are almost certainly important as an additional, and compounding, stress on societies.

High-impact, low-probability events are important when assessing risk from climate change because of their potential for substantial harm to people. Scientists are particularly interested in understanding climate-linked thresholds, beyond which large nonlinear shifts in subcomponents of the Earth’s system occur. Although likely caused by intensive land-use, poor resource management policies, and naturally occurring drought rather than climate change, the 1930’s Dust Bowl of the central United States nonetheless illustrates the severe social and economic impacts that can accompany unforeseen shifts in climate conditions. Since research has not sufficiently characterized many details of these climate-linked thresholds, including early warning indicators, crossing them is possible over any future timeframe. Potential future tipping point processes include:

- Very rapid die-offs of many critically important species, such as coral or insects
- Rapid conversion of Amazon and other rainforests to grassland
- Massive release of carbon from methane hydrates or permafrost carbon
- Discontinuous decrease in summertime Arctic sea ice
- Rapid melting in West Antarctic or Greenland ice masses
- Weakening of the regional North Atlantic Ocean convection belt
- Increased strength of El Niño-Southern Oscillation
- Weakening of the Atlantic Meridional Overturning Circulation belt
- Changes in the West African Monsoon

Rapid-onset processes—particularly arising from socioeconomic or technological sectors—that offset or slow climate change effects, are also possible.
Stresses to Human and Societal Systems

Climate-linked events are disruptive to humans and societies when they harm people directly or substantially weaken the social, political, economic, environmental, or infrastructural systems that support people. For the next few decades, which represents the era of committed climate change irrespective of future greenhouse gas emissions, we expect that climate change will amplify existing stresses while also creating new ones for human and societal systems. Some stresses will be localized or limited to particular sectors, while others may have worldwide implications, such as disruptions to the global food supply (Figure 4).

### Figure 4: Examples of Climate-Linked Stresses to Human and Societal Systems

| Direct impacts from extreme events, such as droughts, floods, fires, and storms | Decreased surface water and groundwater resource supply and access | Reduced water quality from droughts or heavy rainfall |
| Increased species extinction and redistribution, and population reductions | Coastal impacts, such as flooding, submergence, surges, and erosion | Redistribution of catch potential for fish and invertebrates |
| Loss of marine biodiversity that support humans | Depressed crop yields and increases in yield variability | Risks to food access, utilization, storage, and price stability |
| Risks to global supply chains, such as food, minerals, and products | Shifts in production zones of food, fiber, and fuel crops | Decreased energy system integrity and reliability |
| Adverse effects on key economic sectors, such as insurance and tourism | Deterioration or loss of housing or shelter | Declining work productivity, especially from extreme heat |
| Decreased integrity and reliability of infrastructure | Disruption of ecological food webs | Increased displacement of people and changes in migration patterns |
| Negative repercussions on human health, including injury, disease, and death | Changing or emerging geographic domains, such as the thawing Arctic | Loss or degradation of resource-dependent livelihoods, such as agriculture and pastoralism |
| Loss of territory or infrastructure to sea level rise | Change in distribution of disease-carrying organisms | Increases in frequency, range, or toxicity of harmful algae |

Though not exhaustive, this chart illustrates the multiplicity of potential stresses that could intensify or emerge from climate change.

Climate change will also produce beneficial changes for some populations. For example, glacier melt could lessen water stress for perhaps a billion Asians over the next few decades, and most plants grow better under increased levels of carbon dioxide under optimal conditions. The balance of documented evidence to date suggests that net negative effects will overwhelm the positive benefits from climate change for most of the world, however.
National Security Implications of Climate Change

Climate change will affect U.S. national security interests over the next twenty years through multiple concurrent and compounded pathways. The following sections illustrate some significant national security concerns, but examples provided are illustrative rather than comprehensive.

Global Perturbations

No country will be immune to the effects of climate change over the next 20 years, but some will be able to cope, adapt, or respond more effectively than others. Most populations are likely to encounter multiple stresses across political, social, economic, and human security domains—fragile states in Sub-Saharan Africa, the Middle East, and Central and Southeast Asia are especially vulnerable. Local problems could spill over with global consequences, such as through increased human displacement, natural resource disputes, commodity price volatility, or violence.

Studies of potential economic costs from climate change vary considerably. Most estimates show limited aggregate damage to the global economy over the next 20 years, however economic damage to some nations or regions could be severe. Past and anticipated extreme climate events may discourage investments in regions deemed especially vulnerable, and insurance rates may rise well before actual adverse climate effects are felt. Progress on development, particularly in low-lying coastal areas, may stall or recede. A harsher climate also will stress or harm infrastructure not designed for such conditions, especially in urban settings. The financial burden of adapting and responding to emergent climate hazards and crises while expanding efforts to mitigate greenhouse gas emissions could reduce money available for other investments.

Threats to human health will emerge or intensify from climate change. Some groups of people are especially susceptible to climate-sensitive health hazards such as periods of extreme heat. Examples include young children and the elderly, populations experiencing social marginalization through poverty or migration status, and individuals already suffering adverse health conditions. Water-borne diseases such as diarrhea are highly sensitive to climate conditions. Long-term changes in climate could gradually shift the geographic range, seasonal timing, and transmission intensity of infectious diseases worldwide. Health care infrastructure and delivery systems are also likely to be affected.

Food security will almost certainly decrease in some regions. The precise impact of climate change on agriculture production will differ by region and crop, but damages are likely to be greater for countries located closer to the equator. Elevated overnight temperatures will put particular pressure on agricultural productivity. Fisheries productivity is likely to decrease in some areas, such as East Asia. Livestock will be increasingly vulnerable to periods of extreme heat and drought.
Climate change effects could undermine important international systems on which the United States and its partners are critically dependent, such as trade routes, food and energy supplies, the global economy, and domestic stability abroad. Poorly designed adaptation and mitigation responses to climate change could undermine long-term U.S. economic, energy, and security goals. Ongoing climate-related hazards, and the perception of Western responsibility, may engender hostility towards the United States or other industrialized countries.

Instability

Most, if not all, countries are unable to respond fully to the risks posed by climate-linked hazards under present conditions. With increased pressure from climate change, existing social and political structures will come under greater strain, which could deepen grievances and stoke tensions. Impacts would disproportionately fall on vulnerable populations, such as youth. The consequences likely will be severe enough in some instances to compel international reaction, including from the United States. Countries with weak institutions, low governmental legitimacy, or where the potential for conflict and political strife is already present, will have increased risk of instability. Cross-border displacement to neighboring poor countries may undermine regional stability.

Heightened Tensions over Natural Resources

*Water.* Decreases in water access, quality, or reliability may increase the risk of conflict between populations who share river basins or aquifers, especially at the subnational level. Although water is typically a source of cooperation between countries, extreme water scarcity or rapidly changing conditions could change this dynamic. Tensions are especially inflamed when an upstream country builds infrastructure, such as a dam, without a water-sharing agreement with downstream countries.

*Fisheries.* Disputes over fishing rights and access to fisheries have become major points of contention for countries that rely heavily on fishing for food or income. Ocean acidification and warming is likely to redistribute marine fish populations, benefitting some regions at the expense of others, while global fisheries face additional pressures from overexploitation and declining ocean health. Intensifying coral bleaching will harm reef ecosystems crucial for vast species of marine life.

*Arable land.* Declines in land resources crucial to livelihoods and sustenance are well-known drivers of local conflict. In some regions, climate change effects will worsen already degraded soil quality with concomitant effects on the people who depend acutely on its productivity.

Human Movement

An individual’s decision to migrate depends on a variety of social and economic factors, and there is little evidence that climate change effects have been the determining factor in these decisions to date. Nonetheless, people are likely to perceive additional reasons to flee their homes because of
compounded climate change effects, primarily due to the loss of access to critical resources. In addition to movement within national borders—especially to urban areas—many displaced persons will migrate into neighboring countries, sometimes as a staging ground for subsequent onward movement towards countries with greater economic opportunities. Many receiving nations will have neither the resources nor interest to host these migrants. Increasingly inhospitable conditions and losses of territory from sea level rise will likely spur some island nations, particularly in the tropical Pacific, to consider relocating large segments of its population elsewhere. Over the next few decades, the net effects of climate change on patterns of migration and statelessness could be dramatic, perhaps unprecedented.

**Humanitarian Crises**

According to the World Bank, an estimated two billion people already live in fragile and conflict-affected areas of the world and, by 2030, at least half of the world’s poor will live in these settings. These populations are at a disproportionately higher risk to climate-linked hazards. While natural disasters have happened for all of human history, extreme events amplified by climate change may pose newfound challenges, particularly when compounded events occur with greater frequency or severity in the same area. The exposure and resilience of people and assets of those affected are critical factors in how crises unfold. As humanitarian emergencies persist, the international community’s capacity—or interest—to respond will be increasingly strained.

**New Geospatial Competitive Domains**

The Arctic region is warming twice as fast as the rest of the globe and undergoing major and rapid transformation. Retreating sea ice creates new possibilities for resource extraction, tourism, and Arctic fishing, as well as new shipping routes between the Atlantic and Pacific, although operating in the Arctic will continue to prove difficult. Disputes over natural resource extraction operations or unresolved maritime limits and boundary claims will likely increase as the Arctic opens.

**Adverse Effects on Military**

Increasing sea-level rise, flooding, drought, temperatures, and extreme weather events will threaten military capabilities and facilities on domestic and foreign territory, including military bases and training ranges. Operations and equipment will also need to be able to withstand harsher weather conditions. Sea level rise and increased frequency of some tropical cyclones, and its associated impacts on erosion, will require significant levels of new surveying and mapping operations to ensure naval traversability and access to ports. Personnel may also be increasingly unprepared or trained for especially severe or novel conditions, such as fighting pests or combatting wildfires.
Heightened Risk of Climate-Linked Surprises

While climate models project continuous, long-term increases in temperature and other variables, scientists warn that sudden, dramatic climate shifts are possible, given the complexity of the system and analogs in the climate record. The Earth’s climate occasionally has undergone extreme shifts that greatly challenge or overpower many species’ ability to adapt, sometimes in as little as a decade or two. A large body of scientific evidence indicates that Earth’s systems are being driven by natural and manmade forces at extraordinarily high rates of change across the atmosphere, biosphere, cryosphere, oceans, and soil. For example, the current rate of increase of atmospheric carbon dioxide is the highest in perhaps 66 million years and at levels not seen in at least 800,000 years (Figure 5).

Figure 5: Carbon Dioxide Levels from 800,000 Years Ago to Present

[Graph showing carbon dioxide levels over time]

Scientists are working out the precise degree to which the climate responds thermally to such pulses of carbon dioxide, but the resultant rate of temperature change is likely unprecedented in modern human history. Many scientists highlight the growing risk that abrupt impacts from climate change will increase over the next several decades and beyond. The national security implications of such changes could be severe.
Closing

The IC’s role is not to predict the future but rather to assess risk and provide strategic warning. From a national security perspective, the disruption imported by climate change and its associated effects over 20 years depends critically on at least four factors:

- The degree to which known levels of carbon dioxide and other greenhouse gases drive global and especially regional temperature increases: a large or small influence, or something in between

- The degree to which the multiplicity of concurrent or sequential climate-linked hazards interact, amplify, or offset each other

- The degree to which the drivers of climate change, particularly greenhouse gas emissions, will be addressed by people, governments, and industries

- The degree to which people’s exposure and vulnerability to known and anticipated climate-linked hazards are reduced

The first two factors are scientific concerns and active areas of academic research; people’s choices in the present and future, however, dictate the magnitude of the last two. The large range of uncertainties means that quantifying the appropriate timeframe for action is difficult—complicated by the fact that responses to stresses will often require many years to bear fruit. Absent extensive mitigating factors or events, we see few plausible future scenarios where significant—possibly catastrophic—harm does not arise from the compounded effects of climate change.

The State Department’s Bureau of Intelligence and Research produced this document and did not coordinate with the rest of the intelligence community in its production.
Statement for the Record

Dr. Rod Schuster
Senior Analyst
Bureau of Intelligence and Research
Department of State

Hearing on
The National Security Implications of Climate Change

Before the
Permanent Select Committee on Intelligence
U.S. House of Representatives

June 5, 2009
Choomoush Shirai, Ranking Member Nunes, and distinguished members of the Committee, thank you for inviting me to speak with you today on the national security implications of climate change.

As a U.S. intelligence officer in the Department of State Bureau of Intelligence and Research, it is my job to provide clear, objective, and independent analysis to policymakers to advance U.S. national security objectives. As a scientist in the intelligence community (IC), I blend insights derived from peer-reviewed journal articles and other scientific reports with information gathered from daily intelligence reporting to provide science-informed national security analysis. My understanding of this and other issues is deepened by the cadre of technical and dedicated officers in the IC, many with technical expertise, who quietly serve U.S. interests. This Committee is already aware that the IC does not advocate for any particular set of policies, including those that address climate change.

The Bottom Line

Fundamental characteristics of the global climate are moving outside the bounds experienced in human history and there is uncertainty on how some aspects of the climate will evolve. Given the complex social and political contexts in which a multitude of changes are occurring, however, we can expect new and compounded stresses on people and societies around the world, many with outcomes important for national security.

Climate change will have wide-ranging implications for U.S. national security over the next 20 years through global partnerships, increased risk of political instability, heightened tensions between countries for resources, a growing number of climate-linked humanitarian crises, emergent geopolitical competitive domains, and adverse effects on military and national security. Increasingly probable amplifications of other security concerns are especially worrisome. Climate change alone is unlikely to trigger state failure in the next few decades but it will affect factors that contribute to conflict, such as access to natural resources. People will increasingly decide to move because of deteriorating conditions, both within nations and into countries that are more prosperous. Perhaps most importantly, the capability of concurrent and compounded changes to Earth’s systems, from human and natural causes, heightens the risk for unforeseen and possibly severe climate-linked surprises.

Frameworks and Analysis

The IC’s task with respect to climate change is to inform policymakers of the myriad risks and uncertainties that may be ahead, rather than trying to predict the future. We have therefore examined a wide range of climate change effects, including those currently believed to have low probability, particularly if the ramifications could be highly impactful. The IC focuses on security considerations outside the United States, so we do not address the direct effects of climate change on the U.S. homeland. We expect, however, that many judgments could nonetheless apply to the United States,

Commented (EMCR): NSC Comment: There could be national security implications of climate change, but these implications differ by region.

Commented (EMCR): IC Comment: Carbon emissions are changing the earth in a way that will have implications for national security.

Commented (EMCR): NSC Comment: There is nothing exceptional about current climate and it is a profoundly important to say that "benevolent" global climate change is moving outside the bounds of human history. There was longer and greater Medieval warming occurring around the year 1500 when Northern Europe expanded Eastward and developed a thriving agricultural society.

Commented (EMCR): NSC Comment: First instance would be political instability in the developing world, but we can’t predict how climate change will be perceived as a trigger or factor, and will likely vary on a regional basis. Consider the effects on Europe.

Commented (EMCR): NSC Comment: There is nothing exceptional about current climate and it is a profoundly important to say that "benevolent" global climate change is moving outside the bounds of human history. There was longer and greater Medieval warming occurring around the year 1500 when Northern Europe expanded Eastward and developed a thriving agricultural society.
Analyzing the national security implications of climate change generally requires tracing a long trail from climate stresses to climate-linked events to societal impacts to security concerns, an endeavor complicated by climate conditions being intertwined in a complex of social, political, and physical conditions (figure 1). Illustrating the large number of other important contributing factors beyond the scope of this document, but notable examples include consumption patterns, demographics, environmental degradation, existing social and political conditions, land use changes, emerging technologies, governance, and the tendency for populations to concentrate in climate-vulnerable locations. Changing climate conditions, in combination with other stresses, almost certainly will increasingly threaten national security over the next few decades.

![Figure 1: Schematic Links Between Climate Change and National Security](image)

**Reliability Note:**

The SC does not develop climate security assessments only on findings from outside sources. Our preferred sources are from U.S. Governmental institutional agencies, such as NAPA, IPCC, and USGCRP and U.S.-based scientists and institutions such as the National Academy of Sciences. We also seek information and analysis from many other domestic and international sources particularly peer-reviewed journals.

**Commented:**

This is due to the purpose of the SCs (that is, to prepare climate change impacts to the state, local, and regional levels) as well as the urgency of climate change. The SCs have a unique role in providing information on climate impacts and adaptation options to a wide range of stakeholders, including policymakers, businesses, and the public.

**Commented:**

The SCs are not the only organizations that focus on climate change and its impacts. Many other organizations, including governments, international organizations, and non-governmental organizations, also conduct research and provide information on climate change. The SCs are meant to coordinate and integrate the findings of these organizations to provide a comprehensive and consistent overview of climate change impacts and adaptation options.

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Rising temperatures in recent decades have driven a suite of climate phenomena, particularly in the atmosphere—such as droughts, floods, extreme storms, and heat waves—and ocean systems, including sea level and ocean chemistry. These changes are occurring at a rate unprecedented in a million years. Climate signals such as rising temperatures are projected to continue and likely accelerate, with impacts on ecosystems, human society, and global economy.

Figure 3: Projected Trends in Selected Climate-Linked Phenomena (2020–2050)

<table>
<thead>
<tr>
<th>Phenomena</th>
<th>Change Confidence</th>
</tr>
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<td>Global mean surface temperature</td>
<td>Weak</td>
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</tr>
<tr>
<td>Hurricanes and tropic storms over land (frequency, duration)</td>
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</table>

Note: Adapted from Composite image. The climate models used are from the Intergovernmental Panel on Climate Change (IPCC). The confidence and change in these projections are based on an analysis of the available scientific literature. These projections should be interpreted as indicating the likely range of possible outcomes. The projections may change as new data becomes available or as scientific understanding evolves.
Figure 4: Examples of Climate-Linked Stresses to Human and Societal Systems

- Direct impacts from extreme events, such as droughts, floods, fires, and storms
- Increased water supplies and withdrawals, and population reductions
- Loss of marine biodiversity that supports human livelihoods
- Reluctance in global supply chains, such as food, energy, and products
- Adverse effects on key economic sectors, such as insurance and finance
- Decreased reliability and vulnerability of infrastructure
- Negative repercussions on human health, including injury, disease, and death
- Loss of habitat or biodiversity in marine and terrestrial ecosystems

Impact on marine biodiversity that support human livelihoods

Reduced water-quality from drought or heavy rainfall
Reframing of global food and production systems
Role of food security, nutrition, and price stability
Disruption of ecosystems and services
Decelerating progress in poverty reduction
Increased displacement of people and changes in migration patterns
Loss of natural habitats or biodiversity
Increased frequency of extreme events

Climate change will also produce behavioral changes for some populations. For example, during a cold winter, individuals might seek out warmer weather and engage in outdoor activities like skiing or snowboarding. Another way to adapt to climate change is through technology, such as using air conditioners to cool buildings, or insulating homes to reduce heat loss. Understanding these behavioral responses is crucial for effective climate change mitigation and adaptation strategies.
Climate change will affect U.S. national security interests over the next twenty years through multiple concurrent and compounds pathways. The following sections illustrate some significant national security concerns, but examples provided are illustrative rather than comprehensive.

Global Implications

No country will be immune to the effects of climate change over the next 20 years, but some will be able to cope, adapt, or respond more effectively than others. Most populations are likely to encounter multiple stresses across political, social, economic, and human security domains—fragile states in Sub-Saharan Africa, the Middle East, and Central and Southeast Asia are especially vulnerable. Local problems could spill over with global consequences, such as through increased human displacement, natural resource disputes, commodity price volatility, or violence.

Studies of potential economic costs from climate change vary significantly. Most estimates show limited aggregate damage to the global economy over the next 20 years. However, economic damage to some nations or regions could be severe. Past and anticipated extreme climate events may discourage investments in regions deemed especially vulnerable, and insurance may not be available to cover actual adverse climate effects. Progress on development, particularly in low-lying coastal areas, may stall or reverse. A number climate also will strain or harm infrastructure not designed for such conditions, especially in urban settings. The financial burden of adapting and responding to emergent climate hazards and risks while expanding efforts to mitigate greenhouse gas emissions could reduce money available for other investments.

Threats to human health will emerge or intensify from climate change. Some groups of people are especially vulnerable to climate-related health hazards such as periods of extreme heat. Examples include young children and the elderly, populations experiencing social marginalization through poverty or migration status, and individuals already suffering adverse health conditions. Water-borne diseases such as cholera are highly sensitive to climate conditions. Long-term changes in climate could gradually shift the geographic range, seasonal timing, and transmission intensity of infectious diseases worldwide. Health care infrastructure and delivery systems are also likely to be affected.

Food security will almost certainly decline in some regions. The precise impact of climate change on agriculture production will differ by region and crop, but damages are likely to be greater for countries located closer to the equator. Elevated overnight temperatures will put particular pressure on agricultural productivity. Reduced productivity is likely to decrease in some areas, such as East Asia. Livestock will be increasingly vulnerable to periods of extreme heat and drought.
Chronic change effects could undermine important international systems on which the United States and its partners are critically dependent, such as trade routes, food and energy supplies, the global economy, and domestic stability abroad. Poorly designed adaptation and mitigation responses to climate change could undermine long-term U.S. economic, energy, and security goals. Ongoing climate-related hazards, and the perception of Western responsibility, may engender hostility towards the United States or other industrialized countries.

**Instability**

Most, if not all, countries are unable to respond fully to the risks posed by climate-linked hazards under present conditions. With increased pressure from climate change, existing social and political structures will come under greater strain, which could deepen grievances and stimulate tensions. Impacts would disproportionately fall on vulnerable populations, such as youth. The consequences likely will be severe enough in some instances to compel international reaction, including from the United States. Countries with weak institutions, low governmental legitimacy, or where the potential for conflict and political strife is already present, will have increased risk of instability. Cross-border displacement to neighboring poor countries may undermine regional stability.

**Heightened Tensions over Natural Resources**

Water. Increased access to water, quality, or reliability may increase the risk of conflict between populations who share river basins or aquifers, especially at the subnational level. Although water is typically a source of cooperation between countries, extreme water scarcity or rapidly changing conditions could change this dynamic. Tensions are especially salient where an upstream country has a large infrastructure, such as a dam, without a water-sharing agreement with downstream countries.

Fisheries. Disputes over fishing rights and access to fisheries have become major points of contention for countries that rely heavily on fishing for food or income. Overfishing and warming is likely to redistribute marine fish populations, benefiting some regions at the expense of others, while global fisheries face additional pressures from overexploitation and declining ocean health. Intensifying coral bleaching will harm not only ecosystems crucial for local communities but also the carbon storage and sequestration capacity of marine environments. Unintended local impacts on coral reefs are likely to affect livelihoods and the health of coastal ecosystems.

Human Movement

An individual's decision to migrate depends on a variety of social and economic factors, and there is little evidence that climate change effects have been the determining factor in these decisions to date. Nonetheless, people are likely to perceive additional reasons to flee their homes because of...
compounded climate change effects, primarily due to the loss of access to critical resources. In addition to movement within national borders—especially in urban areas—many displaced persons will migrate into neighboring countries, sometimes as a staging ground for subsequent onward movement toward countries with greater economic opportunities. Many receiving nations will have neither the resources nor interest to host these migrants. Inclement, inhumane conditions and losses of territory from sea level rise will likely spur some island nations, particularly in the tropical Pacific, to consider relocating large segments of their populations elsewhere. Over the next few decades, the net effects of climate change on patterns of migration and statelessness could be dramatic, perhaps unprecedented.

Humanitarian Crises

According to the World Bank, an estimated two billion people already live in fragile and conflict-affected areas of the world and, by 2050, at least half of the world’s poor will live in these settings. These populations are at a disproportionately higher risk to climate-linked hazards. While natural disasters have happened for all of human history, extreme events amplified by climate change may pose new and formidable challenges, particularly when compounded events occur with greater frequency or severity in the same areas. The exposure and resilience of people and assets in these affected areas are critical factors in how crises unfold. As humanitarian emergencies persist, the international community’s capacity—or interest—to respond will be increasingly strained.

New Geopolitical Competitive Domains

The Arctic region is warming twice as fast as the rest of the globe and undergoing major and rapid transformation. Reclaiming sea ice creates new possibilities for resource extraction, tourism, and Arctic fishing, as well as new shipping routes between the Atlantic and Pacific, although operating in the Arctic will continue to pose difficult. Disputes over natural resource extraction operations or unresolved maritime limits and boundary claims will likely increase as the Arctic opens.

Adverse Effects on Militaries

Increasing sea level rise, flooding, drought, temperatures, and extreme weather events will stress military capabilities and facilities on domestic and foreign territory, including military bases and training ranges. Operations and equipment will also need to be able to withstand harsher weather conditions. Sea level rise and increased frequency of some tropical cyclones, and its associated impacts on retooling, will require significant levels of new surveying and mapping operations to ensure naval traversability and access to ports. Personnel may also be increasingly unprepared or trained for especially severe or novel conditions, such as fighting pests or combating wildfires.
Heightened Risk of Climate-Linked Surprises

While climate models project continuous, long-term increases in temperature and other variables, scientists warn that natural, dynamic climate shifts are unpredictable, given the complexity of the system and analogs in the climate record. The Earth's climate occasionally has undergone extreme shifts that greatly challenge or even completely erode species' ability to adapt, sometimes in as little as a decade or less.

A large body of scientific evidence indicates that Earth's systems are being driven by natural and human-made forces at extraordinarily high rates of change across the climate, atmosphere, cryosphere, oceans, and tectons. For example, the current rate of increase of atmospheric carbon dioxide is the highest in perhaps 80 million years and is levels not seen in at least 800,000 years (Figure 3).

![Figure 5: Carbon Dioxide Levels from 800,000 Years Ago to Present](image)

Scientists are working on the precise degree to which the climate responds thermally to such pulses of carbon dioxide, but the resultant rate of temperature change is likely unprecedented in recorded human history. Many scientists highlight the growing risk that abrupt impacts from climate change will increase over the next several decades and beyond. The national security implications of such changes could be severe.
The IC's role is not to predict the future, but rather to assess risk and provide strategic warning. From a national security perspective, the disruptive impacts of climate change and its associated effects over 20 years depend critically on at least four factors:

- The degree to which carbon dioxide and other greenhouse gases drive global temperature increases: a large or small influence, or something in between
- The degree to which the multiplicity of concurrent or sequential climate-linked hazards interact, amplify, or offset each other
- The degree to which the drivers of climate change, particularly greenhouse gas emissions, will be addressed by people, governments, and industries
- The degree to which people's exposure and vulnerability to known and anticipated climate-linked hazards are reduced

The first two factors are scientific concerns and active areas of academic research; people's choices in the present and future, however, dictate the magnitude of the last two. The large range of uncertainties means that quantifying the appropriate timeframe for action is difficult—complicated by the fact that responses to disasters often require many years to bear fruit. Almost certainly, mitigating factors or events, we see few plausible future scenarios where significant—possibly catastrophic—harm does not arise from the compounded effects of climate change.
NSC Comment: The surface temperature data of Fig. 2 is very controversial. It has been fiddled with to reduce recorded temperatures of early years and to increase temperatures of recent years in order to give the appearance of alarming warming. Temperature records for rural locations, unaffected by urban heat island bias, show much less warming.

Satellite measurements of the temperature of the lower atmosphere since about 1980 also show much less warming. All models find that the atmosphere should exhibit more warming than the surface, not less.

There has been very modest warming in fits and starts since the end of the Little Ice Ages, about the year 1800. This was interrupted by cooling from about 1940 to 1980, leading to ominous predictions of a new ice age. Time, Newsweek, and other journals that are just as confidently predicting uninterrupted warming from now on. A long “pause” in warming began about the year 2000, and the pause may still be in effect.

NSC Comment: The oceans are strongly basic with an average surface pH of about 8.1. Increased concentrations of CO2 should have slightly reduced the pH to around 8.0. This is a completely trivial change compared to the natural fluctuations of ocean pH with time of day, depth, latitude, etc. where pH can range from 8.3 to 7.5. To call an average change of pH from 8.1 to 8.0 “acidification” is propaganda, designed to alarm the chemically illiterate.

NSC Comment: Nobody is sure what will happen to temperatures over the next several decades. Greenhouse gases should cause some warming. But the observed warming has been much less than model predictions, and consistent with 1°C warming, or less, for doubling CO2 concentrations in the atmosphere. This would be an overall benefit to society, for example, by extending growing seasons, curtailing winter mortality.
Ms. JAYAPAL. Thank you. In late March I sent a letter to the National Security Council raising concerns about their decision to assemble an ad hoc Committee headed up by Dr. Happer to provide an “adversarial review” of the federal government’s climate science findings. And in that letter I said, “While any president has the right to ignore or act in contradiction to the advice of top government scientists, it is clear that the goal of this ad hoc Committee is to undermine legitimate science itself, which will make it more difficult for national security officials to prevent and respond to the changing climate.”

This Administration’s interference in this testimony by Dr. Schoonover is exactly what I feared would happen when I wrote my original letter. And I never got a response to that letter. So today I sent a second letter asking for a response to my original letter, which had a series of questions. And I would like to, Mr. Chairman, enter my new letter and my original letter into the record now.

Chairman YARMUTH. Without objection, so ordered.

[The information follows:]
March 25, 2019

Dr. Charles M. Kupperman
Deputy National Security Adviser
Eisenhower Executive Office Building
1650 Pennsylvania Avenue, NW
Washington, DC 20503

Dear Dr. Kupperman:

I write to seek clarification on reports that the National Security Council (NSC) is working to assemble an ad-hoc committee to provide an “adversarial” peer review of the federal government’s climate science findings, and that White House officials are hand-picking scientists who do not represent the consensus views on the impacts of climate change. I am deeply concerned that this closed-door initiative could undermine national security and shape the future of our nation’s work to address climate change in secret, without the public scrutiny required by the Federal Advisory Committee Act (FACA). It is also particularly alarming that avowed climate change denier William Happer will lead this committee. While any President has the right to ignore or act in contradiction to the advice of top government scientists, it is clear that the goal of this ad-hoc committee is to undermine legitimate science itself, which will make it more difficult for national security officials to prevent and respond to the changing climate.

Climate change should not be a partisan issue. As 58 senior military and national security leaders who served in both Democratic and Republican administrations recently wrote, “Climate change is real, it is happening now, it is driven by humans, and it is accelerating.” According to the Fourth National Climate Assessment of 2018, mandated by the Global Change Research Act of 1990, climate change is already affecting U.S. Department of Defense assets, causing the military to integrate climate risks in planning and adaptation. The United States has already spent tens of billions of dollars on infrastructure repairs and reconstruction stemming from extreme weather events and rising sea levels.

Organizations such as the non-partisan Center for Climate and Security and the Henry M. Jackson Foundation have brought together climate scientists, military and security experts, and policy makers to develop collaborative solutions that protect our country from the very real
national security challenge of climate change as a “threat multiplier.” Climate change will add additional stress to domestic and global poverty, causing conflict, environmental degradation and public health risks and increasing instability that directly affects our national security. Deliberately undermining decades of research and expertise in the face of such risks is foolish, short-sighted and irresponsible.

Simply put, this White House’s denial of climate change is putting the American people at risk. The administration released the Fourth National Climate Assessment which concludes, “human activities...are the dominant cause” of global warming, and President Trump replied, “I don’t believe it.” President Trump appointed a former coal lobbyist as EPA Administrator who fired a panel of scientific experts charged with assisting the EPA’s review of air quality standards. Now, the NSC reportedly will be naming a well-known climate denier as head of this ad-hoc committee.

Dr. Happer’s views on climate science are well out of the mainstream. Dr. Happer is not a climate scientist and is associated with several climate denial organizations such as the Climate Exit Coalition (CLEXIT) and the CO2 Coalition, of which he is the founder and former board president. In 2015, Peabody Coal paid $10,000-$15,000 to Dr. Happer for his testimony on carbon dioxide at a hearing held by Minnesota Public Utilities Commission, which he donated back to the CO2 Coalition.

Given the disturbing reports about your decision to place Dr. Happer in a position where he will be charged with undermining the federal government’s response to climate change, I request that you answer the following questions to provide clarification on the nature of the proposed National Security Council initiative:

1. Are the reports accurate that the White House is considering forming an ad hoc “adversarial” NSC panel to address climate change issues? If so, why are you forming this panel and what is its mission?

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8 https://www.flickr.com/photos/usaclimatedata/43458327991/in/photolist-7AHLTQ-9tVt3v-5aS2f1-e3XKRL-7aa6vD-7aS74S-6vQHJH-7a8ksy-5aS4s7-7a8y4z-6v7nMm-6vQHd9-7a80gj-6v7nNQ-7a86vG-7a86wa-7a86rO
2. The Department of Defense’s 2019 Worldwide Threat Assessment identified "negative effects of environmental degradation and climate change" as risks to global security. Will the Defense Department officials responsible for the conclusions of this analysis be represented on the new panel?

3. The 2018 National Climate Assessment predicts that due to climate change, "annual losses in some economic sectors are projected to reach hundreds of billions of dollars by the end of the century." Will the Administration officials responsible for these conclusions be represented on the panel?

4. Why was Dr. Happer chosen to lead this NSC initiative on climate security?
   a. What is his current role in the White House?
   b. What formal climate science training has he received?
   c. What peer-reviewed research on climate science has he published that will inform the NSC initiative?
   d. Does the Administration agree with Dr. Happer’s previous statement that “the demonization of carbon dioxide is just like the demonization of the poor Jews under Hitler”?

5. What other officials are presently being considered for the panel? What criteria was used to choose them?

6. How will the panel coordinate with the National Science and Technology Council and the Office of Science and Technology Policy?

7. How will the panel coordinate with other national security agencies in the Administration? Has the White House established any formal protocols for interagency coordination?

8. How often will the panel meet? How will the Administration ensure that opposing views within the climate science community are proportionally represented?

9. How will the public receive regular updates on the Council’s work?

10. What is the proposed chain of command for the NSC initiative on climate science?
11. Will the panel be subject to FACA rules and regulations?

12. What energy and industry organizations has Dr. Happel worked for that could create a conflict of interest?

13. What actions is the Administration taking to address conflicts of interest for panel members?
   a. Will panel members be required to disclose potential conflicts of interest?
   b. Will panel members be required to sign the President’s ethics pledge?
   c. Will panel members be considered government employees subject to all applicable conflict of interest rules and regulations?

I ask that you respond to these questions by April 5, 2019.

Climate change will only continue to endanger our national security. Top climate scientists predict that within 12 years, it will lead to severe flooding, droughts, extreme heat and poverty for hundreds of millions of people. Climate change is creating refugees, claiming lives and costing taxpayers billions of dollars. Addressing this threat requires strong leadership from the Administration led by trained experts on climate science – not chockfranna hand-picked to undermine the scientific and policy consensus on emerging national security threats.

Sincerely,

[Signature]

PRAMILA JAYAPAL
Member of Congress

CC: Dr. Kelvin Droegemeier, Director, Office of Science and Technology Policy
June 11, 2019

Dr. Charles M. Kupperman  
Deputy National Security Adviser  
Eisenhower Executive Office Building  
1650 Pennsylvania Avenue, NW  
Washington, DC 20503

Dear Dr. Kupperman:

I write to follow up on a letter I sent you on March 25, 2019, regarding the role of Dr. William Happer, an avowed climate science denier, at the National Security Council. Although I requested a response to the questions I posed in my letter by April 5, 2019, I have yet to receive one.

This weekend, both The Washington Post and The New York Times reported that Dr. Happer played a leading role in blocking the written testimony of Dr. Rod Schoonover, a top intelligence agent at the State Department, in last week’s House Permanent Select Committee on Intelligence hearing on the “National Security Implications of Climate Change.” Given these disturbing reports, the questions I raised in my March letter are more pertinent than ever. Congress, and the public, deserve to know what role Dr. Happer is playing in setting administration policy and whether he is undermining our national security by interfering with the critical work of our intelligence community.

I respectfully ask that you respond to the questions in my original letter (enclosed for your convenience) by June 18th, 2019, exactly one week from today.

Sincerely,

Pramila Jayapal  
Member Congress

CC: Dr. Kelvin Droegemeier, Director, Office of Science and Technology Policy
Ms. JAYAPAL. Thank you. The Trump Administration’s attempt to bury critically-important scientific analysis by our top intelligence agents is horrifying and dangerous. It is not the job of the president to actively undermine the work product of dedicated civil servants in our intelligence community, like Schoonover or Dr. Hayhoe, who has done such incredible work on climate science. It really puts our country and the entire globe at risk. And I very much hope that my colleagues across the aisle, if they really care about this issue, will not just show up to this hearing to talk about everything but climate, but will actually work on affecting and reducing, mitigating climate change.

Thank you, Mr. Chairman, I yield back.

Chairman YARMUTH. The gentlelady’s time has expired. I now recognize the gentleman from Oklahoma, Mr. Hern, for five minutes.

Mr. HERN. Mr. Chairman, I am glad we are having this hearing today. This is a good opportunity for us to explore how these ideas fundamentally and practically won’t work, in addition to their stunning cost.

I take exception to we shouldn’t be worrying about the cost. Climate change must be addressed without sacrificing our country’s economic and fiscal well-being. Destructive policies like the Green New Deal, something we don’t apparently want to talk about today; extreme theories such as the modern monetary theory, which argues that we can simply print more money to correct Congress’s fiscal wrongdoing.

In my home state of Oklahoma, one in five jobs is directly or indirectly supported by the oil and natural gas industry. For example, in my district the Williams Company employs 1,250 Oklahomans; Magellan Midstream Partners employs over 900. Oklahoma’s priority on energy dominance has paved the way for local entrepreneurs such as Valerie Mitchell of Corterra Energy and Don Burdick of Olifant Energy to take on a massive personal risk that results in job creation, giving back to the community, and stimulating Oklahoma’s economy.

In fact, in 2018 the oil and natural gas industry was also the largest source of tax revenue in my state, directly paying over $2 billion in taxes, including the annual $555 million-plus that go directly to education, and almost $90 million that go directly to our state’s infrastructure. My home state of Oklahoma’s energy industry employs hundreds of thousands of people, and generates more than $50 billion, annually. Oil and gas companies bring high-paying jobs to Oklahoma, and have been the single largest contributor to state revenue in recent years.

Under the toxic Green New Deal we would lose those jobs and the important impact those companies have on my state. While my friends on the other side of the aisle are so focused on advancing some of the most extreme proposals in Washington, they are unfortunately ignoring the demands for jobs in some of their own states.

For example, in Minnesota my colleague, Representative Pete Stauber, has worked tirelessly, and been outspoken in the support of replacing an old pipeline known as Line three to make it safer. It is currently corroded and only about at half of the capacity, potentially creating roughly 8,600 jobs over a two-year period, which
building trades are saying they are strongly supporting. There is an old and unsafe pipeline, which can be improved, modernized, and made more efficient. Yet some of our colleagues prefer forcing a large-scale transformation of society, which the Green New Deal suggests, over the needs of our local communities.

Also in Minnesota mining projects would produce the precious metals used to make wind turbines. Yet some of my Democratic colleagues oppose those initiatives, as well. The U.S. then relies on China and other foreign countries with little or no labor protections. This is very sad. It is a shame.

Furthermore, several other states are blocking this type of critical energy infrastructure, including New York and Washington State. New York has blocked multiple natural gas pipelines, despite its growing northeast demand for gas, a move that not only impacts Williams jobs in my district, but also forces New York state to rely on foreign oil, which is more expensive than domestically-produced sources of energy, and with lesser environmental standards. Blocking those projects denies consumers even beyond their state's borders access to more affordable energy.

It seems as though some Democrats are listening to radical environmental activists, instead of working, seeking new jobs in their districts, and consumers looking for lower energy bills.

That said, my questions today are directed to you, Mr. Cass. Talks of Democrat proposals such as the Green New Deal have an astronomical price tag. And yes, it matters, $93 trillion. To pay for it, taxes would be severely raised on every income level. But even these drastic measures would only pay for a fraction of the Green New Deal. Not only is this legislation detrimental to our state's economy and key industries, but it also would destroy the country's economy.

As I just expressed, many of our constituents' jobs rely on the oil and gas industry. If we implement the Green New Deal, would our constituents experience job losses?

Mr. Cass. That would be my understanding of the Green New Deal.

Mr. Hern. And what would cause that?

Mr. Cass. Well, the premise of the Green New Deal would be to shift our energy consumption away from conventional fossil fuel sources and toward alternative sources, reducing demand for the conventional sources.

Mr. Hern. Such as, like, airplane pilots and those kind of things. We wouldn't be flying any more, according to the fact sheet, the infamous fact sheet.

Mr. Cass. I am not sure what to make of the fact sheet.

Mr. Hern. Okay, I just wanted to make sure. Thank you for your answer. You know, on March 26, 2019—I know there has been a conversation here that many of the Democrats don't support it. But the Senate voted down the Green New Deal by a vote of 0 to 57. And many of those actually endorsed it and cosponsored it. So, in fact, 43 Senators refused to even cast a vote at all. So their silence speaks volumes.

Mr. Chairman, I yield back.

Chairman Yarmuth. The gentleman yields back. I now yield five minutes to the gentleman from New York, Mr. Morelle.
Mr. Morelle. Thank you, Mr. Chairman, for holding this hearing on an important topic. And I would, for one, would like to associate myself with the comments made by Mr. Peters about this topic, generally.

And I will say, before I get to the questions, I am frustrated. For all the talk today about the Green New Deal, which is not before us, and modern monetary theory, the truth is that the science on climate change is pretty much universally accepted now in the scientific community among most people in the country. And the idea that, when we are talking about the economic or the fiscal impacts of it, we break down not on this side—not on that side of the table, but on this side of the table, having this silly argument—to me, it is just incomprehensible.

We have a problem. It is a significant, it is a persistent, it is a growing problem. And it will continue to affect people in this country and around the world. We ought to work together, I think, as Mr. Peters eloquently said, to try to find real solutions to it.

And I do appreciate very much, Mr. Chairman, you having this hearing.

I will say, just for me, I represent Rochester, New York, which is on the southern shore of Lake Ontario. In 2017 we had catastrophic flooding. We are experiencing record levels again today. I was with Governor Cuomo and most of his cabinet who had come to Rochester yesterday to what—excuse me—to announce $300 million being spent by the state of New York. That is on top of $100 million that we spent two years ago to help homeowners and businesses and municipalities deal with flooding.

There may be a whole host of reasons, but it certainly seems to me weather patterns, record rainfall, snow runoff, and associated weather patterns have had a profound impact just on the state of New York, and will continue to have here.

So I wanted, if I might, Dr. Hayhoe, what do we know about how climate change is increasing the frequency and severity of storms, heavy rainfall events? There seems to be a fair amount of opinion, again, on this side of the table about what the severity is. But can you talk about that, both inland as well—and affecting the river system, as well as coastal, and how attribution science advanced in the past few years?

Dr. Hayhoe. I am originally from the other side of the lake from you, and southern Ontario also experienced devastating and unprecedented flooding this year. We know that storms and floods have always happened naturally. But in a warmer world, air holds more water vapor. So when a storm comes along, as it always does, today there is more water vapor for that storm to sweep up and dump on us than there was 50 or 100 years ago.

And one of the places that we have seen the biggest observed increase since the 1950s, and the frequency of heavy precipitation, has been in the U.S. Northeast and the Midwest, which puts Upstate New York in exactly the middle.

Mr. Morelle. And the—I assume you gather data on this. So is there reliable information we can get on—as it relates to attribution of weather patterns and increasing temperature?

Dr. Hayhoe. Heavy precipitation has been formally attributed—or, I should say, the observed increase in heavy precipitation has
been formally attributed to human-induced climate change for quite some time. The signature is very distinct.

Mr. Morelle. The—it is interesting. This wasn’t my original question, but as I am thinking about it—I only have a minute-and-a-half left, and I am sorry for that, but the—I was recently at the Institute on Sustainability at Rochester Institute of Technology, the world famous—they travel around the world, talking about how to reduce the carbon footprint in manufacturing, lean manufacturing, and helping businesses try to get to zero emissions. And they were talking about how, you know, even in a world in which we will clearly combust renewables—there is a whole science around biomass and other ways to generate heat—they talk about the—sort of the capture—why carbon captured and petroleum and other products are so much of a challenge, because you are releasing centuries and centuries of carbon into the atmosphere.

Could you just comment on that, so—it helps people, I think, who think about—we are still going to be burning biomass or other—or anyone else on the panel can certainly address it. But the science around that would be helpful.

Dr. Hayhoe. Yes. So when we burn biomass—trees, crops, agricultural waste—we are burning things that contain carbon that took that carbon out of the atmosphere just years or decades ago. So it, essentially, is carbon neutral. When we burn coal and gas and oil, we are digging up and burning sources of carbon that have not seen the atmosphere for millions of years.

And, as the National Climate Assessment concludes, as far back as we can go, at least 50 million years in the past, there has never been a time when this much carbon was being released into the atmosphere this fast.

Mr. Morelle. Thank you, Mr. Chairman.

Thank you for the answer. I yield back my time.

Chairman Yarmuth. The gentleman’s time has expired. I now yield five minutes to the gentleman from Utah, Mr. Stewart.

Mr. Stewart. Thank you, Mr. Chairman. And as always, to the witnesses, thank you for being here and for your efforts to prepare yourself for this hearing.

I do have questions, and—but I feel compelled to make kind of some observations about some things I have heard here, and in other hearings such as this.

I want you to know that I accept that climate change is real. I think we have redefined a little bit what that means. It has changed a little bit. But the climate is certainly always changing. It is something that we need to accept, and we need to try to understand.

I also accept that human behavior is contributing to it in some way. I can tell you that I have spoken with—including the former director of the EPA and other very, I would hope, knowledgeable individuals on this, and asked them how much of this can we attribute to man and to human behavior, and the answer she gave was, “We don’t know.” And I think that is an honest answer.

Some of you are shaking your head, but that is an honest answer. We don’t know. Some people think they know, but there is much disagreement on how much of this is directly attributable to man.
So the question, I think, is what do we do, and how can we best mitigate this? How can we mitigate the impacts of it?

Look, I don’t want to beat up on the Green New Deal. Talk about beating a dead horse; that horse has, I think, been dead and buried. It is the greatest gift given to the Republican Party in a long time in many ways. I believe it is unserious, I believe it is based on fear-mongering, I think it is steeped in the heavy-handed government power that would cost—destroy the American Dream for us and for our children.

But I think now what it comes down to is what do we do? And I just think there is a better way. There has to be a better way. And that is where I would like to bring, then, to my question. And I think, Mr. Cass, I perhaps would ask you.

Among all these projections of the drought, and flooding, and family violence, and related deaths, et cetera, if the earth keeps warming, there are some market solutions to some of these. And I would be interested if any of you have thoughts.

Again, Mr. Cass, I would look to you to maybe begin. But look at—help us understand some of the success of free enterprise, democratic and market-driven solutions that would maybe help mitigate some of these concerns.

Mr. Cass. Sure. I think when we are talking about how to address the problem of climate change, it is important to realize we are having two conversations. One is about what is mitigation, meaning what can we do to reduce the amount of carbon dioxide and greenhouse gases we are releasing, and then one is about adaptation, meaning how can we cope effectively with any change that does occur?

On both sides I think free enterprise and innovation can be and have to be central to the solution. So, from the mitigation perspective, if we want, in particular, to reduce emissions globally—at the end of the day it is global emissions that matter—we are going to have to have technologies for the developing world that are more attractive than fossil fuels. And we don't have those today. And so, continued innovation and, actually, the development of new and better technologies has to be part of the program.

On the adaptation side, you know, one of the wonderful things about adaptation is that it tends to happen fairly naturally, if people have the right information, and if they have the right incentives. So, as an example, if someone is a coastal property owner, if they understand the best-available scientific forecast for sea-level rise, and they understand that they are going to be on the hook if their property faces damage, they will respond rationally by building resilience, by community-wide investing in protection, and potentially, in some cases, by moving away over time.

If they don't have good information, or if they don't have good incentives. If we tell them the federal government is going to pay for whatever happens to them, then they won't react. And so I think, on the adaptation side, it is the information and the incentives that policymakers really have to get right.

Mr. Stewart. Well, and I think exactly right. I mean—and this is a fairly—some people think this is complicated, but it is really not, and that is the rational behavior of people through incentives. And you can either compel them through a very, very heavy-hand-
ed government, or you can incentivize them and expect, as we have for several thousand years, that people will respond rationally and what is in their best interests.

And I will conclude in the last half-a-minute that I have, and that is to emphasize one other thing you said, and that is this has to be a global solution. Without partners on this, we can’t fix this ourselves. And the truth is that our partners are dishonest and disingenuous in their commitment to this, many of them.

I don’t think China has any intention at all of impeding the growth of their economy for the next 20 years in order to address climate change. I don’t think Indian does, either. They have hundreds of millions of people in poverty they have to lift up to the middle class; that is their goal. And they won’t allow U.S. policy on climate change to impede them in that goal. And if we don’t recognize that we can’t do this ourselves, and find something that works globally, then we are beating our head against a wall.

Mr. Chairman, thank you. I yield back.

Chairman YARMUTH. Thanks. The gentleman’s time has expired. I now recognize the gentleman from Texas, Mr. Doggett, for five minutes.

Mr. DOGGETT. Thank you very much. The inconvenient truth is that we have a global climate crisis. And whether you call it the Green New Deal or a climate action plan, what we need is bold action, and we need it now. And ignorance and delay and avoidance and denial is not such a policy.

Last month we had carbon dioxide reaching the highest level in the history of human existence. And last week we had the Trump Administration still trying to prevent a State Department official from testifying about the catastrophic potential of human-caused climate change. The Trump Administration always prefers political fantasy to science and scientific fact. They have questioned and harassed so many scientists across this country, one agency after another, that you have to begin to wonder if they believe in gravity.

Of course, willful ignorance of climate change is not a laughing matter. Across America we are seeing with our own eyes the impact of inaction: severe and erratic weather, 100-year floods that become 100-month floods; 60 inches of rain in the energy capital of America in a very short period of time: Houston, Texas; West Nile virus and Lyme disease, that were once uncommon, afflicting more and more of our neighbors. These changes, of course, will be disproportionately impacting the most vulnerable, our children and our seniors.

Since everything is bigger, in fact, in my home state of Texas, the impact of climate change is more far-reaching there. Of course, Texas is the state that produces the most carbon pollution and the most climate deniers, increasingly leading now with the most climate disasters. The National Climate Assessment predicts rapid swings from extreme drought to flood and sea-level rise along the Texas coast, twice the global average. In Texas we have always had two summer temperatures, hot and hotter. But now it is just hotter, as we are on track for 30 to 60 days of over-100-degree temperatures every year.

Just a little bit of prevention would go such a long way towards cost savings.
And there is reference to the marketplace. Well, yes, in the marketplace one company after another—what insurance company would not consider the impact of human-caused climate change? What business along our coast wouldn’t consider that? There are market answers. But in 2017 the 16 extreme weather disasters in the United States had a market impact. They cost over $313 billion.

We see companies around the globe that are changing what they are doing. They are expending billions of dollars because they know they could face trillions of dollars in loss. The cost of continuing to do nothing is impacting much more than polar bears and exotic locations in travel magazines.

Energy-efficient alternatives shouldn’t be the alternative; they should be the standard.

Trump always says that he hates losers. But he has picked the losing coal industry. And coal, the war on coal, has been very real. And coal has lost. It has lost in the marketplace to cleaner Texas natural gas and renewable energy.

Of course, the Trump Administration would say that our years and years of record-breaking heat isn’t a dangerous sign of climate change. I guess they would call it alternative climate.

I believe that we must treat climate change as a national security concern, as have so many senior defense officials.

The Green New Deal, while aspirational and imperfect, offers a road map far stronger than the do-nothing Republican alternative of rejecting science in favor of obstruction. Just as a little bit of prevention goes a long way toward cost savings, a little temperature increase goes a long way toward disrupting our weather patterns. We have got to do more than just pray for rain in modest amounts.

Dr. Hayhoe, I appreciate the testimony of all the witnesses. But as a fellow Texan, I would ask you, since you have testified in front of both the Austin and San Antonio City Councils, do you believe that these local climate action plans are important to adopt in the face of inaction in Washington? And what do you see as the impact in Texas of climate—the climate crisis?

Dr. Hayhoe. Well, first of all, in our state of Texas, we are seeing that our natural patterns of feast, and famine, flood, and drought, are being amplified across much of the region. This is affecting our agriculture, our water, our urban infrastructure, and more. City-level plans absolutely make a difference, both in preparing and building resilience to the impacts of a changing climate, as well as to weaning ourselves off the fossil fuels that are the primary cause of this issue.

DFW Airport is the first carbon-neutral airport in North America.

Mr. Doggett. Thank you.

Chairman Yarmuth. The gentleman’s time has expired. I now recognize the gentleman from Texas, Mr. Roy, for five minutes.

Mr. Roy. I thank the Chairman. I thank the witnesses for taking time out of your schedules to come here and join us today.

Ms. Hayhoe, I would say to you my dad is a Texas Tech graduate, grew up in West Texas. And I will tell you, I took him to Minneapolis for the basketball game, which seems like a magnanimous
and awesome thing to do for your father, until you realize that I went to the University of Virginia. So—but I was sitting with Jody Arrington, who is the congressman from Texas—from Lubbock, and Texas Tech made a great run.

But I appreciate you being here. I do want to pick up on a few things that have been said here today, and offer a few thoughts.

But first of all, that I think it is really important, as we think about this issue, to factor in human flourishing and the world—the benefit that is provided for humankind by the clean, abundant energy. You know, in the 1870s the average American family, 80 percent of their income was on food, shelter, and clothing. Today is it about a third. We have seen a—in the 1955, for example, only 2 percent of the American people had access to air conditioning. By 1980 it was 50 percent. Over the last 100 years, deaths from climate-related events have fallen from somewhere in the zip code of half-a-million to 20,000, while the population has nearly tripled.

We have created an environment because of adaptation that was previously discussed by a witness that is critically important to recognize in the context of what we are talking about.

You know, today, however, if you look around the world, you still have a billion people—a billion—without access to electricity. You have 2.7 billion, 38 percent, who are using biomass and dung, basically, for fuel, for cooking. You have got half of the world population lacking enough electricity for the essentials that we just take for granted in the United States today. You have hospitals in countries that are not first-world countries, where you have got doctors having to squeeze bags to keep babies alive on incubators. Here, we don't have that problem.

So what I would ask for the people, as we are going through these issues, to put a little perspective on the benefits that we have in this world and our lives, from access to abundant energy. And then we got to figure out, well, how are we going to get that energy?

And if you look at what has been happening in the world, where people have sort of bowed down at the altar of this sort of climate change hysteria, instead of dealing with it head on, and thinking about making sure there is clean, abundant energy, you have Germany, where retail electricity is up 50 percent from 2007 to 2017 because of taxes and subsidies; $24 billion increase—I am sorry, $24 billion euro in 2017 is the cost of direct—and of the direct taxes and subsidies for renewable energy. The IHS estimated net export losses to Germany due to high electricity prices of $52 billion euros from 2008 to 2013. Meanwhile, the carbon dioxide in Germany has fallen only 9 percent from 2003 to 2016.

Now, you talk about partisanship here. Who produces the most natural gas in the world? I am proud to say, as a Texan, it is Texas. Who produces the most wind energy in the United States? I am proud to say, in Texas, it is Texas. We got a quarter of the nation's wind energy. We just cracked 19,000 megawatts in December of wind production.

But it is still a fraction of our overall peak demand. And it does have consequences in that conversion. And if you think about that, let's strike a balance. Who was doing that? My former boss, Governor Rick Perry. Oh, the dastardly Republicans, who bury their
head in the sand on energy. We were creating a all-of-the-above approach in Texas. But there are no just magic energy trees.

I am always amazed—I was at an event one time and there was somebody in the crowd, and they said, “Well, where are we going to get power if we don’t use fossil fuels?”

And this person said, “Electricity.” Like just magic generation of electricity.

We have to have power to have what we enjoy in this world. And, you know, I think if you think about what the—on the terms of these impacts, I would say that we got to think about it here in the Budget Committee, about what the actual impact will be on civilization, if we go down the road of the Green New Deal. We have enormous benefits in terms of life expectancy, in terms of the benefit that we have to our families, our children, jobs, access to hospitals, access to clean air and water. If you overlay the freest countries in the world with a map of those that have the cleanest environments, it is almost a direct correlation.

We will lead this fight if we think about what we are trying to produce in terms of access to clean energy, and making sure that we have got abundant energy to make our lives better.

And with that I will yield back.

Chairman YARMUTH. The gentleman’s time has expired. I now yield five minutes to the gentlelady from Illinois, Ms. Schakowsky.

Ms. SCHAKOWSKY. Mr. Cass, I just wanted to ask you a yes-or-no question. Let me see. Where did it go?

I have information here that says the Manhattan Institute has received funding from the Koch Brothers. The Claude R. Lambe Foundation, one of the Koch family foundations, reported giving all—over $2 million to the Manhattan Institute. Is that correct?

Mr. CASS. I don’t know, I am sorry.

Ms. SCHAKOWSKY. Okay. I think it is. I am really frustrated in this hearing today.

And what I am hearing is that those people who feel a sense of urgency about what is happening to our planet—actually, the planet will probably do better without us. But to the preservation of our species right now, that there is an urgency about this, that, in fact, in the last year—and one of you, I think, can confirm this—that we actually saw an increase in carbon emissions. And I wonder if you could—one of you could talk about that, 3.4% or something like that last year, in 2018. Doctor——

Dr. HAYHOE. That is correct. U.S. emissions did increase last year. And globally, carbon emissions continue to increase.

Ms. SCHAKOWSKY. You know, 20 years ago—a reporter found that over 20 years ago—when I was in the state legislature, I made a speech on the floor of the House about how we have to get serious about this. And then he followed up with me not too long ago. And I said, you know, “Twenty years and we are going in the wrong direction.”

It seems to me—am I overstating this? This is existential. This is about the future of the young people that are in this room.

I agree in the—noticing what Congressman Peters did, that young people are here. But that is because what I am hearing in my district is from young people.
Can you—can anybody talk about this in terms of, really, the—why we have to have a sense of urgency now?

Dr. Hayhoe. The first time that scientists formally warned a U.S. President of the risks and the dangers that climate change posed to our society was over 50 years ago, and that president was Lyndon B. Johnson.

It is not, as you stated, our planet that is at risk. It is not even our species. It is our civilization. It is everything that makes our lives worth living. And it absolutely is our economy, as well. We have progressed tremendously over the last 300 years, and I am actually very grateful, personally, for the benefits fossil fuels have brought us. But just as we transitioned from horses and buggies to automobiles, in the same way we must now transition our energy systems into the future to ensure our continued security.

Ms. Schakowsky. So the President of the United States, when he was running for office, said that he would break the Environmental Protection Agency into little tidbits. That is what he talked about.

There is a hearing going on also in Energy and Commerce on what is happening to the Environmental Protection Agency, and the kinds of changes that have happened. What should we be expecting from regulation right now?

I am worried about the Midwest. That is where I am from. We have floods, many of our farms are under water. But I am also worried about climate refugees, because I think we are seeing that already. And if we want to stop people coming from places where they can’t farm any more to the United States, we better do something about this. What do we need to do, in terms of regulation?

Dr. Hsiang. I think, at present, we are very poorly equipped, from an institutional standpoint, to cope with what we might expect to see, in terms of the influx of migrants, migrants coming from other countries as well as the internal displacement of Americans. I think the Dustbowl is maybe the closest analog we have to what we might expect to see in the Midwest, with roughly a 25 percent chance.

And so, thinking about the movements of our own internal populations trying to cope with climate change, it is a form of adaptation, and it is incredibly costly to the people who have to pick up and move their lives.

Ms. Schakowsky. So I was sitting on Lake Michigan. Is someone going to be coming after this source of water? Are people going to be moving?

Dr. Hsiang. It seems implausible that the places where people are currently conducting agriculture and making their livings are going to be the same places in the future where people can continue to make livings.

Ms. Schakowsky. Thank you. I yield back.

Chairman Yarmuth. The gentlelady yields back. I now yield five minutes to the gentleman from Georgia, Mr. Woodall.

Mr. Woodall. Thank you, Mr. Chairman. I will pick up where Ms. Schakowsky left off.

Given that you have about 25 percent of the world’s fresh water close by, I can promise you that we in the deep South will be com-
ing for your water one day. And I want to—I just want to prepare folks for that.

I also want to ask Mr. Cass the easy yes or no question. I actually have two for you. If Ms. Schakowsky is able to wrangle up some dollars from anywhere on the ideological spectrum to help you do your research, are you willing to accept those dollars?

Mr. Cass. I have no role in fundraising at the Institute. So you would have to ask them.

Mr. Woodall. Then I will ask the opposite question. Does the quality of your research vary, based on where the funding for the Institute comes from?

Mr. Cass. No.

Mr. Woodall. I tell you. I have been incredibly pleased, Mr. Chairman, with this hearing. I did not expect to come and be inspired, but I really have been.

Dr. Hsiang, it was your testimony about managing the climate—well, managing the earth as an asset that got me started in the right place, because I think that is something we can agree on, up and down the ideological spectrum. We all understand managing assets. And managing assets doesn’t mean there is a foregone conclusion of where we are going to go, it just means we are going to try to maximize that ability.

Dr. Hayhoe, for you to say it is not about preservation of the species, it is about preservation of the civilization, there is a quality of life here that we are operating on, too. I think there is just so much that we can agree on.

Mr. Woodall. I put back up Mr. Cass’s chart here, because I do have a complicated time sorting through which facts are the facts, and which facts are the angle.

[Chart].
Effect of extreme temperature on mortality
Does anybody disagree with what he has put on the board here, to say that the research is projecting that Pittsburgh is going to have 12 deaths per 100,000 because of extreme heat, but Phoenix today only has 0.17? Is—does anybody disagree with those conclusions?

Dr. Hsiang. In a careful review of Oren Cass’s earlier work, we were unable to confirm these numbers.

Mr. Woodall. But, I mean, is—that is—these—we are talking about orders of magnitude here that, yes, if I look at the numbers on the right, I am incredibly frightened. But when I look at the numbers on the left, I am incredibly comforted that there should be some sort of agreed-upon metric.

Now, I don’t—you don’t have to agree it is 12.8 instead of 12.7, but is double digits right on the one hand, and fractional digits right on the other? Again, I—if we can agree on that, foundationally, it just seems that it offers us a different place to have a conversation.

Dr. Hsiang. I think the three bars on the left do not come from a peer-reviewed analysis. And, in fact, I have no idea where they came from. And we were unable to confirm them when we tried to understand what Oren Cass did in his earlier calculations.

Mr. Woodall. The—Mr. Cass, sure.

Mr. Cass. Yes. In my paper that I assume he is referring, it cites specifically to the website at EPA that provides a downloadable spreadsheet from which those numbers come.

And could I also add that the 2017 version of the EPA study actually provides a map that shows these numbers in circles. And you can go straight to the EPA study and find the map that shows in the year 2000 those are the values, and in the year 2100 those are the values.

Mr. Woodall. Well, I would just share with you this whole conversation about adaptation, it is the first time I have heard it from a witness panel. Generally—my chairman excepted—when we call witnesses, we sometimes get the most extreme views on both sides, and the opportunity for conversation is eroded. But yes, I am not talking about stopping everything I am doing today. We are going to continue to progress.

Let me ask about nuclear energy for a moment, because carbon is the—is our baseline. We are getting ready to move an energy and water appropriations bill to the floor of the House. It has—contains zero money for licensing Yucca Mountain. As you know, that is a political issue. We have spent billions out there. This isn’t to open it, this is just to license it, to finish the studies. If we opened it today it would be full, because we have so much nuclear material across the country that needs to be stored.

Is it the position of folks at the desk—do we have a position, in terms of addressing climate change, on supporting nuclear energy and, thus, providing safe storage?

Dr. Hayhoe, do we have a position?

Dr. Hayhoe. There is not a formal position among climate scientists. But I can tell you for sure that it doesn’t produce carbon pollution.

Mr. Woodall. we used to be the largest coal-burning state in the nation. We are on our way to being the—having more solar genera-
tion and more nuclear generation than any other place. But I need that all-of-the-above strategy to work with.

I appreciate what you said about renewables, in terms of forestry, too. In Georgia, trees are crops, just like corn and cotton are. You don’t clear-cut your land and leave it there. You manage it, you cut it once, you cut it again, you replant, you do all of those things to be a good steward of the land that you love. But the EPA has grappled with that. The European Union is grappling with where to continue that.

Is it an agreed-upon, settled conversation here in the States, that biomass is, in fact, carbon neutral?

Dr. Hayhoe. It depends on how it is grown. If more energy is put into growing it than burning it, no.

Dr. Hsiang. Absolutely.

Dr. Hayhoe. Yes.

Mr. Woodall. Mr. Chairman, you have been generous. I thank you very much. And I thank you all for the conversation today.

Chairman Yarmuth. The gentleman’s time has expired. I now yield five minutes to the gentlelady from Texas, Ms. Jackson Lee.

Ms. Jackson Lee. Mr. Chairman, thank you very much, and to the Ranking Member, as well, and to my colleagues. It is important that every single Committee that has jurisdiction on this question, I believe, should be engaged in the question of climate change, because it is a impactful condition that is going to skew the economic health of the nation. And it certainly, for me, poses a serious question why everyone is not looking, reviewing, researching, and that those who are climate deniers as to the impact, I would argue vigorously or suggest further in-depth consideration of the numbers I am about to give you.

In 2018 we had $306 billion in cost from natural disasters; 16 disasters were a billion-plus in costs. We were dealing with five of the warmest years. Just those mere facts, and the evidence of what I witnessed as an impacted individual—and my constituents—in Hurricane Harvey, which saw 51 trillion gallons of water to create an ocean in the City of Houston.

Now, I want to say to my friends in energy that I represent those constituents, as well. What I have said to the multi-nationals is let everybody know that you are engaged in research on climate change and renewables. Let everybody know that you are aware, because of your scientists, of what can transpire as relates to this issue of climate change.

I don’t know how anyone can proudly claim themselves a denier. They did not walk in my shoes. They did not walk in the 12 to 1,500 people who died in Hurricane Katrina, the 3,000 to 4,000 who died in Puerto Rico, only to be discovered way late, when Harvard University used its research to determine how many died. And, obviously, wildfires and the massive flooding that just occurred in America the last three weeks across the landscape of the Midwest.

So I believe this is a crucial and important discussion. Let me quickly—I am going to give three questions. And if you can answer them—and I will give them all at this point.

Dr. Hayhoe, how is climate change expected to impact water supplies, drought, and wildfires in various regions of the country? And
why are we seeing both increased flooding and increased drought—i.e. in the state of Texas, Austin, and that west area, or middle of the state area we are seeing that.

Dr. Hsiang, if you would, comment on the assessment—estimate that the future cost of inaction on climate change could reach roughly 3 percent of the national GDP annually by the end of the century. What is the right way to think about these estimates, and the way we should use them to plan for the future?

And then I want to ask Mr.—sorry, I can’t see your name right now. If you would, follow up on the same comment about the cost of climate change. And you may incorporate something else.

My time is short, but if you all could go ahead, I yield to you on the answers, that this is an imperative that we understand this.

Dr. Hayhoe. Wherever we live, our precipitation follows natural patterns of wet and dry, wet and dry. If we live in Texas, it follows natural patterns of wet and dry and wet and dry. And as the planet warms, this natural pattern is being stretched in both directions.

Warmer air means more water vapor. When a storm comes along, it picks it up and it dumpp on us, creating heavier rain. When the storms don’t come along, during drought, it means longer and stronger droughts.

Ms. Jackson Lee. Doctor?

Dr. Hsiang. I would like to confirm that the number you mentioned is in the reasonable range of previous estimates.

Thinking about what large fractions of GDP could be lost from climate change is like thinking about just paying a tax, except you get nothing in return. So we estimate that just replacing destroyed assets during hurricanes, even in the state of Florida, is going to cost roughly 12 grand a year. And it only cost 14 grand to go to Berkeley, where I teach. But instead, you will just be replacing broken things, you won’t be getting an education in return.

Ms. Jackson Lee. So a massive cost.

Dr. Gómez, you are with U.S.—

Mr. Gómez. Sure. From our perspective, we look at climate change from a fiscal exposure, and so we have reported on the variety of areas on which the federal government is exposed, being a owner of facilities, an insurer of property, and also crop insurance, and then also in the provider of disaster aid.

I just wanted to mention—in your question about impact on water supply, so GAO currently is doing an audit at the moment, looking at the resiliency of water infrastructure systems across the country. You mentioned how Houston was devastated by it, and how the—its own water infrastructure was affected.

Ms. Jackson Lee. Yes.

Mr. Gómez. So we are looking at ways in which some water systems are building resilience into their structures. So we hope to get that report out to you folks soon.

Chairman Yarmuth. The gentlelady’s time is expired.

Ms. Jackson Lee. I thank the Chairman.

Chairman Yarmuth. I now recognize the gentleman from Texas, Mr. Crenshaw, for five minutes.

Mr. Crenshaw. Thank you, Mr. Chairman. My generation cares a lot about climate change and a clean environment. And so I, too, care about it. And we have a vested interest in developing cleaner
energy and ensuring that the air we breathe is clean. No one would dispute that, despite the highly dishonest claims about denialism from the other side. That kind of language is meant to divide and cause resentment.

But I also have an interest in getting to the truth of the problem, the actual cost we can expect, and the most reasonable, efficient, and plausible solutions. This is where our true—our two sides differ, fundamentally.

The narrative on the left is that catastrophe is looming, and that no cost is too high. Well, of course, this isn’t true. Costs do matter. Proper estimates of our ability to adapt to climate change matters. Common-sense analysis of the problem does matter. A true cost-benefit analysis free from political bias does, in fact, matter.

So let’s do away with some of the most absurd claims right away. For instance, that climate change will cause not just heat-related deaths in massive numbers, but hundreds of thousands more murders and sexual assaults. That is what was testified earlier. Is this a serious claim? No, it isn’t. Of course it isn’t. You make such a claim if your goal is to torpedo good discussions right off the bat. Oren Cass, here testifying today, has already done an excellent job debunking the bad and, frankly, highly dishonest economic modeling used to come up with those absurd numbers, so I won’t dwell on that.

I do want to dwell on real solutions, not insane, Green New Deal solutions based on a false premise. Not a Paris Climate Agreement, which foolishly undermines the most innovative economy in the world, the United States, while freeing up China and India to continue pumping out emissions, or any other ridiculous solutions that rely solely on solar and wind. These are feel-good solutions. They are based on flowery notions of vision and purpose, as opposed to serious policy ideas.

Serious policy ideas will take advantage of the greatest innovation machine the world has ever known, the U.S. economy. And we should be focused on providing the world with cheap, clean energy that can thrive in the marketplace.

The U.S. is responsible for around 15 percent of global emissions. That is what a Green New Deal would address, 15 percent. For an enormous $93 trillion price tag you address just a fraction of the problem. We should be addressing 100 percent of the problem. And the only way to do that is to export our expertise.

In Houston we have a privately-backed investment, like the net power plant. It is in La Porte, right outside my district. This plant burns natural gas to generate electricity, which is already cleaner than most fossil fuels, and is readily available in the Permian Basin, just two hours away from Texas Tech. The thing is, this natural gas plant has zero emissions. It captures the carbon it emits, and recycles it into the power plant. No emissions. And it is self-sustaining.

Natural gas fracking has had an enormous impact already, reducing our emissions greatly. What if we did a better job exporting clean, natural gas to dirty coal-burning countries like China and India?

Well, we can answer that. The Department of Energy estimates that the promise of natural gas plus carbon capture is so great that
if China and India switched just their coal-burning boilers to natural gas, they would reduce emissions by 43 percent. Adding full-scale turnover to natural gas and carbon capture, and you are looking at an 88 percent reduction in carbon emissions. More natural gas exports, carbon capture technology, modular nuclear reactors, research on nuclear fusion: these are the future. They work. And they can make our air cleaner, keep growing our economy, and provide sustainable energy for our growing global needs.

We must also invest in adaptation, as human beings have been doing for thousands of years. There is a reason that climate-related deaths have dropped drastically over the last 100 years, by around 90 percent, even though our population has increased by orders of magnitude.

We must have realistic projections of the cost of climate change, followed by realistic solutions. That is the way forward.

My time for a question—Ms. Hayhoe, if I may give you one question, there is a lot of estimates on the cost. But what I never hear, and what I think the right question to ask is, if we implemented the most extreme solutions—let's just assume the Green New Deal. Let's assume 0 emissions in 10 years coming out of the United States. What would be the effect on the global—what would be the global effect of that? What would be the temperature effect? What would be the effects after that? Do we measure those things?

Dr. Hayhoe. First of all, if you look at cumulative emissions, which is what climate does respond to, the U.S. is responsible for just under 30 percent of those.

If the U.S. eliminated its emissions, it would actually have an impact beyond its current 15 percent because, as you pointed out, that technology would percolate around the world, and that leadership would have a huge impact in places that are emerging economies and developing——

Mr. Crenshaw. What technology? What technology does the Green New Deal create?

Chairman Yarmuth. The gentleman's time has expired. Thank you.

I now recognize the gentleman from Nevada, Mr. Horsford, for five minutes.

Mr. Horsford. Thank you very much, Mr. Chairman. One of the areas that really hasn't been explored today is the impact of climate change on the poor and marginalized communities. And, you know, with all due respect to those who want to focus on one proposal, I would like to focus on the people who are actually impacted.

Extreme heat conditions and increases in air pollutants negatively impact the health of my constituents, increasing cardiovascular and respiratory illnesses. And, even more alarmingly, sometimes leading to premature death. Further, these incidences of illness are having a devastating impact on people's quality of life, to live a healthy life, to be able to raise their family, and to work.

In my home state of Nevada, a desert state, it is particularly vulnerable to the changing climate. In Nevada we face droughts, particularly impacting Lake Mead, which supplies water to roughly 25 million people across Nevada, California, and Arizona. Forty-six percent of Nevadans live in areas that face dangerous wildfires.
And Nevadans face an increasing number of heat waves. By 2050 it is projected that the City of Las Vegas will experience 106 days per year with temperatures upwards of 105 degrees Fahrenheit. In fact, if you open the newspaper today, we are experiencing a severe heat wave, with temperatures over 105 degrees through Thursday.

The consequences of climate change disproportionately affect pregnant women, children, the elderly and disabled, minorities, and poor communities.

So Dr. Hsiang and Dr. Hayhoe, what evidence is there confirming that climate change will have more severe impacts on low-income and other vulnerable and marginalized populations?

Dr. Hayhoe. The best description I have heard of climate change is that coined by the U.S. military, which calls it a threat multiplier. It takes issues like poverty, illness, lack of access to clean water, economic hardship, and it exacerbates them in very specific ways.

Dr. Hsiang. We are now able to measure these types of inequality that you are describing. For example, you can take a wealthy family and a poor family, and have them try to experience the exact same heat wave. And because the wealthy family has more resources to cope with it—maybe they can go to the movies to stay cool, or do something else—the poor family is then struggling, and often substituting away from other types of things that they would need to spend on. They might take money out of their clothing budget, or their food budget to try and cope with some sort of disaster.

So there is mounting evidence that climate change and the events that come along with climate change will actually widen the existing inequality across the country today.

Mr. Horsford. And you talked about inequality, as far as health and quality of life. What about income inequality, and how climate change is impacting people in the United States?

Dr. Hsiang. That is a very good question. For example, we often see that lower-income households are participating in industries where they are exposed to outdoor temperatures for long periods of the day. So people working in agriculture, people working hard in construction, those individuals are the most heavily impacted, in terms of their ability to work and their living for their families, when exposed to increasingly adverse outdoor conditions.

Mr. Horsford. So you touched on agriculture and construction, which are two major industries in Nevada.

Also leisure and hospitality, which is the largest economic sector in Nevada, accounting for 27 percent of our workforce. So can you elaborate further on how more extreme temperatures will cause lost working hours for outdoor laborers, particularly those working in these industries, and how they are impacted?

Dr. Hsiang. Absolutely. We have numerous studies using government data on how much work people are able to supply, how many hours people are allowed to work and earn their wages. And we find that people, when the temperatures start exceeding, you know, 80 degrees, temperatures regularly experienced in Nevada, we see that people start being able to work less. And the time that they are working, they are less productive. So their employer is also getting less bang for their buck, in terms of paying these workers.
Mr. HORSFORD. Thank you, Mr. Chairman. Again, I appreciate you holding this hearing on the devastating impacts that climate change is causing to individuals. But I think particularly those who are in marginalized communities and from poor communities deserve to have a voice in this process. And we need to have a policy that works for them, as well.

Thank you, and I yield back.

Chairman YARMUTH. The gentleman's time has expired. I now yield five minutes to the gentleman from Tennessee, Mr. Burchett.

Mr. BURCHETT. Thank you, Mr. Chairman and Ranking Member. I have only been here about, I guess, less than 120 days. So I haven't been here long enough to be bitter towards anybody. So I will—my comments will be—I am sure, if you check back with me after 200 days, then I might have changed my position.

So—and I appreciate all these young folks here, and I want to encourage you all. Because what ends up happening, in my 100-plus days of being here, is, you know, one side points the finger at the other, and the other one does the other, and then we all go out and issue a press release, and we tell our folks back home, “Look what we are doing,” and nothing gets done. Nothing gets done.

And I am a conservative. I have no—and like this young lady, I am—I try to be a Christian. I am on the forgiven end. And I appreciate you, because we all need to be good stewards. But I am also a capitalist.

And I am—thought he was coming up to take the mike away from me.

But you know, we talk about the Chinese and the Indians. The Chinese are putting 300 new coal plants online. That—you talk about pollution. And their safety controls are probably something that we would have not done in the 1970s. India, the Ganges River, their most sacred river, it is horribly, horribly polluted. Their landfills have been described as time bombs.

And I want to encourage you young people—and I am a capitalist, as I stated, but I think capitalism plays a huge role in this.

At one time I was the mayor of Knox County, and I used to read these statistics, and we generate about one tire per person per year. And if you can figure out what to do with those tires, young folks, Bill Gates will be calling you all for a loan, because it is—the devastating effect of those things that you just see every day, and it just kind of gets ingrained in you, and you don't pay it much attention.

And I would encourage, as I have done since the 1970s, to compost. You always talk about what can we do? We are not going to do a dadgum thing up here. You all are going to have to do it. And you should do it in your own communities. You should compost, you should recycle. Make sure you get the ratio 20 to 1, because if it goes the other way, you get that awful smell. Then you are putting some very noxious gases into the atmosphere, outside of just the carbon that you get in a 20-to-1 ratio when you turn it.

I think God has given us some great solutions, I just think we have turned our back on Him in more ways than one, and we are not looking at what is going on around us.

And I do represent east Tennessee. And east Tennessee is home to Oak Ridge National Laboratory and the Tennessee Valley Au-
And I am wondering—and they both have a huge influence on our nuclear power—or nuclear power, as some people say.

And I am wondering. Do—the question is to—I would like to ask every Member. Just a quick, short answer. Do you all support nuclear power? And where do you see improvements in it, possibly in the funding?

Start here, and just go down the line, if that would be all right.

Mr. Cass. Yes, I do. I think we need to fund more innovation on new reactor types, and we need to make sure it is eligible for any subsidies that other zero-carbon technologies are eligible for.

Mr. Burchett. Right.

Mr. Gómez. So at GAO we don’t take a position, sir, on energy. But we do audits on any type of energy that Congress wants us to look at.

Mr. Burchett. All right. Safe answer, thank you.

Dr. Hsiang. We don’t have a—I don’t have a position on nuclear power, but I think careful economic analysis indicates that it is a decliningly—it is becoming increasingly expensive, and the rate of return on those investments to the ratepayers tends to be declining over time.

Dr. Hayhoe. And, as a climate scientist, I am in favor of any form of energy that does not produce carbon, can be done safely, including both operations and disposal of waste, and can be done cost-effectively. And I think that is where the biggest improvements remain to be made in nuclear.

But the small modular reactors that were mentioned previously are a positive step in that direction.

Mr. Burchett. Thank you. And Oak Ridge National Laboratory is leading the way in that direction. And I look forward to them in the future.

And Mr. Cass, where do you see the free market? See, there you go, we are out of energy already.

[Laughter.]

Mr. Burchett. Where do you see the free market having the biggest impact in the United States’ energy markets?

Mr. Cass. In terms of innovation and new technologies?

Mr. Burchett. Yes, sir.

Mr. Cass. Well, I think, at the end of the day, it is going to be private-sector innovators that are going to drive a tremendous amount of—somewhat on the research, certainly on the development and the deployment side.

And so they need to face—they need both a good flow of research and new technologies coming toward them from the universities, and then they need to be facing a market where they will have a chance to enter and compete.

Mr. Burchett. Thank you. And you young people, don’t get bitter up here. You all get out and solve the problems, all right? Thank you all.

I have become an old man. I am 54, and I am calling these folks young people, Mr. Chairman. I have become my father. But thank you.

Chairman Yarmuth. The gentleman’s time has expired. I now yield five minutes to the gentlelady from Minnesota, Ms. Omar.

Ms. Omar. Thank you, Chairman.
So Dr. Hsiang and Dr. Hayhoe, are you all offering flowering ideas in solving our climate crisis?

Dr. HAYHOE. I am a climate scientist, and we are really good at diagnosing the problem, telling you what is happening, why it is happening, and how bad it is going to be. But we are not a one-stop shop. We need everyone. We need engineers, we need business people, we need innovators, we need creators. We need all of us, really, on board to fix this thing and to make sure that we end up in a better place in the future, not worse.

Dr. HSIANG. I think the entire field of economics uniformly agrees that what we need is to somehow find a way to put a price on carbon. And, in fact, it is a market solution which is consistent with aligning everyone’s incentives with increasing national and global welfare.

And so, most of the research that we are being—that we are conducting at the Climate Impact Lab, and a huge amount of research at Berkeley, is trying to understand what is the appropriate price to put on carbon. And there is a variety of options. You can do cap and trade options, you can charge something at the pump. There is lots of ways to deal with it. And I think the moment you put a price on carbon, markets will respond instantly. Markets are very efficient, they know how to move resources around. It is a very effective strategy.

Ms. OMAR. In your testimony, Dr. Hsiang, you say that the estimate for the Hurricane Maria will set Puerto Rico back two decades of progress. What would be, like, the cost associated with trying to catch up that progress that could have been made for two decades?

Dr. HSIANG. Just to be clear about what that statement was trying to say, what we see is, when communities are struck by hurricanes, they lose a lot of assets, things that they have spent a long time accumulating, things that are productive. Businesses close. And so, if you were to look at the trajectory of Puerto Rico over time, it was going this—it was increasing steadily, and then it gets hit by a storm. And what we expect is that it will never catch up. It is kind of like when you are riding your bicycle with your friends. If you slow down for a short period of time, you fall behind. And even if you get going at your original speed, you never catch up with your friends unless you pedal a lot faster for a while to catch up.

And so, what we would need to do is we would actually need to gas the economy a lot. We would need to put in a lot of investments to sort of re-inflate all the things that were lost. And so right now we are not on track to do that.

Ms. OMAR. I mean, so we are not only talking about the costs associated with the loss of infrastructure. We are not only talking about the cost associated with the loss of business. We are also talking about the cost associated with the loss of the human life that would have been able to create that production, as well.

Dr. HSIANG. Yes. A lot of the research out there indicates that, actually, the loss numbers that you see in the newspaper, in terms of damages from a hurricane, are roughly only one-tenth of the actual economic loss. Most of the loss shows up as foregone earnings
in future decades. But most people are not very good at keeping track of money they didn’t earn, right?

Ms. OMAR. Yes.

Dr. HSIA NG. But what we see is that that is actually 10 times the cost of the number that you read in the newspaper as the damage, which is really just accounting for sort of buildings and structures that have fallen down in a very short period of time.

Ms. OMAR. Yes. I mean so let me get back to what one of my colleagues earlier was trying to address so eloquently, from the point of view of what this means for poor communities.

We know that there is a cost associated with the kind of crisis that is being created because of pollution. In my district, one zip code, 55411, has the highest asthma hospitalizations in the state. And these are communities that are mostly African-American. And, you know, we are talking about 230,000 asthma attacks in children, 188,000 missed school days and work days each year.

There is cost associated with that, as you have pointed out in some of your research. It seems like we are investing and subsidizing the fossil fuel industry, and exasperating this problem. So there is a double cost to society. How do you propose we mitigate that?

Dr. HSIA NG. Again, as I said before, I think we need to put a price on carbon.

Ms. OMAR. I have a proposal to get rid of this welfare system to the fossil fuel industry. I think it is really important for us to take a stance and make sure that we are making investments in poor communities around our country.

And in regards to composting, I also have a zero waste grant bill that will help communities get that going. And so I am hoping my colleague will help sponsor that so we can try to make sure that we are doing our part in having a sustainable environment. Thank you.

Chairman YARMUTH. The gentlelady’s time has expired. I now recognize the gentleman from Massachusetts, the Vice Chairman of the Committee, Mr. Moulton, for five minutes.

Mr. MOULTON. Thank you, Mr. Chairman. I was one of the first Members of Congress to sign on to the Green New Deal as a signal to what a priority it must be for America to lead the world in addressing climate change. But I also signed on when it was an empty framework. And I believe it is critical that the Green New Deal focus on three major goals.

First, investing in carbon-free energy technologies and other green technologies to lead the world in de-carbonizing our country. Economically efficient policies like a carbon tax, will incentivize the private sector to help; massively increasing our deficit, as some colleagues of mine have proposed, will not help.

Two, while America should set the pace for the developed world, the share of carbon output coming from the developing world increases every year. We, therefore, need to develop the distributive power technologies necessary to bring carbon-free power to rural communities around the globe.

Three, we need to develop carbon capture technologies. Although some activists believe doing so gives us an excuse to keep polluting, the truth is that it is already too late to live without carbon cap-
ture, because of how much carbon we have already released into the atmosphere. Doing these things is the boldest way to stop climate change, and it will grow American jobs. The two should go hand in hand. We have already broken our climate; we don’t need to break our economy to fix it.

Now I would just like to ask a few questions of some Members of the panel, starting with Mr. Gómez.

Mr. Gómez, what are the largest sources of carbon-free energy in the United States today?

Mr. Gómez. Sure. So, according to the Energy Information Administration, last year, in terms of total energy consumption, 12 percent comes from renewables, and 8 percent comes from nuclear.

Mr. Moulton. Great, thank you very much. Now, Mr. Gómez, with regards to national security, GAO declared the federal government’s fiscal exposure to climate change as high-risk, and estimates the value of infrastructure owned and operated by the Defense Department worldwide to be about $1 trillion.

In January Defense reported roughly two-thirds of mission-critical installations are vulnerable to current or future climate impacts. What would be the cost of building new infrastructure, or moving facilities to preserve our national defense strategy?

Mr. Gómez. That is a really good question. And I don’t believe that GAO has estimated that cost yet. But as you said, there is a really large infrastructure with a high asset value.

We focused on making recommendations to the Department to better prepare its facilities, to make sure that it is building in resilience, but also that it is incorporating climate change risks to its everyday planning that they do for their facilities, so they can be better prepared.

Mr. Moulton. I can tell you, as a Marine veteran, that when I visit installations around the world, American military officials, American general officers, repeatedly advise us about the national security threat of climate change.

Dr. Hsiang, the Intergovernmental Panel on Climate stated with high confidence that limiting global warming to 1.5 degrees Celsius with no or limited overshoot would require rapid and far-reaching transitions in infrastructure, including transportation. To what degree are we currently making transportation investment decisions based on limiting climate change?

Dr. Hsiang. That is primarily outside my expertise, but I would say, from what is visible, very limited progress in that regard.

Mr. Moulton. I mean it is interesting to think about a country like France, where a high percentage of travel, relatively speaking, is done by high-speed rail running off of nuclear power plants. And so you essentially have a fast, modern—way faster than anything we have in the United States—transportation system that is carbon-free.

Mr. Cass, I want to give you a chance to chime in here, as well. Our President tweeted that, “The concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive.” Mr. Cass, do you agree with the President’s assessment?

Mr. Cass. No.
Mr. MOULTON. So how is it that people are going to make rational decisions, if the President of the United States is providing completely irrational assessments like that?

Mr. CASS. I think there are, unfortunately, a lot of counter-productive and irrational statements made by both people who refuse to accept what scientists are telling us about climate change, and those who wildly overstate the problem, in that, for instance, Bernie Sanders saying that——

Mr. MOULTON. So you would put President Trump in the category of people who refuse to accept the reality of climate change?

Mr. CASS. I have not spoken with him about it. That is how I would characterize that tweet, certainly.

Mr. MOULTON. Great, thank you very much, Mr. Chairman, I yield back.

Chairman YARMUTH. The gentleman yields back.

So, Mr. Womack is not going to be coming to the Committee. He would normally question at this time. So, instead of that, and since the two of us are the only Members remaining, Mr. Woodall is going to be allocated five minutes to make a closing—closing remarks, and then I will conclude with my questions.

Mr. WOODALL. Because we do have such a learned panel here, is there anyone here who believes we should be setting climate policy based on anybody's last tweet that goes out the door?

[Laughter.]

Mr. WOODALL. Is Twitter the best foundation for good climate policy that we have?

I really am grateful that you all are here.

I wanted to ask the audience that is behind you, though. You all are protected. You are in the circle of trust here on the Budget Committee, but also the camera is facing this way, instead of that way, so you will not be on the hook for anything that you do. But I just wanted to get a show of hands.

We talked about the urgency of climate change. Who feels the urgency that is here today?

All right. Let the record reflect that is a lot of hands, Mr. Chairman.

Put those hands down. We have also talked a lot about nuclear today, most recently with the gentleman from Tennessee. How many folks think that part of our strategy going forward is going to include nuclear energy?

All right. Fewer hands, but still a lot of hands.

I was with one of my Democratic colleagues the other day, and she said, “Rob, we are never going to do a big, public works project like the Hoover Dam again, because you Republicans just refuse to pay for it.”

And I said to her, “No, I am happy to pay for it, but you refuse to give me the permits to build it.”

How many folks—we still have some hydro opportunities here, but we haven’t built major hydro projects in a long time, because of environmental concerns. How many folks would say that expanded hydro is part of our pathway forward? I have got many, many fewer hands this time around.

You all might not have seen all the urgency hands that went up, but I have a tough time in this business of compromise that is
Washington, D.C. melding the urgency with the “Oh, but we can't do it that way,” and, “No, that shouldn't be part of the solution.”

Dr. Hsiang, you said your opposition to nuclear was that the economics weren't there as they should be, but you expressed great faith in the free market. If we move to a carbon tax, my concern is we don't take our thumb off the rest of the scale. We would continue to have laws that disadvantage hydro, we would continue to have laws that disadvantage nuclear. In your vision of a carbon tax that would immediately bring the market forces to bear to solve the problem, would you see a repeal of all of the other laws that put their thumbs on the scale of what the outcome of energy choice should be?

Dr. Hsiang. I think whether or not we put a price on carbon is unrelated to whether or not we do or do not choose to change any other policies in the market.

But just to clarify my earlier statement, I have no particular opposition or support for nuclear power. All I was stating is that the price has, relative to other energy sources, been rising. And so the investments seem to have a declining rate of return over time. That is all.

Mr. Woodall. The—let me ask you, Mr. Gómez, because I know you can't talk policy, but you are absolutely right about federal exposure. I certainly think of that as something that would bring us together on both sides of the aisle.

In fact, on the Budget Committee four years ago—four terms ago—we tried to begin budgeting for disaster, saying let's look back over the last three years of disasters and put that amount of money, the average, aside for next year. We do a terrible job of budgeting for disaster. Does your examination of that lead you to any conclusions why—again, it should be a shared value—we have struggled to better budget for tomorrow?

Mr. Gómez. So—right. So we make recommendations to agencies, right, to improve and to get more information. So we have some recommendations outstanding exactly to that point.

So we have recommended that the Office of Management and Budget, for example, in their funding reports that they provide to Congress, provide information to you all on those programs that face growing fiscal exposure. So then you can then make tradeoffs, as you look at the information, to see what to focus on, both in the short term and the long term.

Mr. Woodall. There is not a single serious problem up here that I have seen solved without trust amongst folks. And sometimes I show up at hearings that erode that trust, and sometimes I show up at hearings—much more rarely—that build that trust.

Going back to your closing statement, Mr. Cass, there are those things that are not helpful when folks ignore the world around us. And there are also those things that are not helpful when folks seek to scare the dickens out of us. I can go down a laundry list of public policy decisions that are—that can be framed in exactly that way.

I just want to thank you all.

I do believe, Mr. Chairman, while we have virtually zero jurisdiction in this space outside of what Mr. Gómez has come here to try to get us to focus on, I do not believe there will be another hearing
on this topic that has as much opportunity to provide a pathway forward among folks who still continue to have substantial policy disagreements. And I thank you all for the role you play in that. I yield back.

Chairman YARMUTH. I thank the gentleman. I now yield—Mr. Panetta sneaked in, so I now yield five minutes to the gentleman from California.

Mr. PANETTA. Thank you, Mr. Chairman, I appreciate that introduction and using the appropriate word of sneaked, rather than snuck. Thank you.

Gentlemen, ma’am, good afternoon. Sorry I have not been here; I had some other obligations. But obviously, thank you for your presence here. And more importantly, thanks for your preparation to be here. I know it takes a lot. But obviously, with your expertise, I am sure it is a lot easier for you to be here than it would be for many of us in this room. So thank you very much.

I am just going to kind of dive right into it.

Dr. Hsiang, if you could—and I know in your testimony that I read you spoke about the substantial net-negative impacts of unmitigated climate change on the U.S. economy. I come from the central coast of California—Monterey, Big Sur, Santa Cruz, what I would contend is the most beautiful district in the nation. Others would disagree, but I would not. Especially if you have been there, you would understand.

But could you elaborate on the economic costs of climate change on coastal homes and businesses, such as my community, and explain, if you can, what fraction of these costs will be attributed to physical damages versus the loss of economic opportunity? Please.

Dr. HSIANG. There are a variety of costs associated with coastal communities. Sea level rise is clearly one of them. And sea level rise is one of these costs where it is very difficult for us to constrain the amount of uncertainty. So there was a very recent study coming out suggesting that it is possible—there is roughly a 10 percent chance of getting some very rapid rises in sea level over the next coming decades. And it is hard to rule those out.

In addition to having higher sea levels, as storms come in—so particularly on the East Coast, less of a problem for California—each storm that comes in pushes a wall of water ahead of it that is the surge in front of a hurricane that then floods homes and does a huge amount of damage. As the sea level rises, and then those storms intensify, those surges become larger and more difficult to manage.

We will probably adapt to those storms by investing in fortifying our coastlines. So actually, the United States is one of the worst-performing countries at our income level in terms of managing storm risk. If you look at a country like Japan, they actually suffer much lower mortality rates in their storms. But part of the reason is because they have an essentially fortified coastline. It is not as an enjoyable place to live if everything is covered with concrete sea walls.
Mr. PANETTA. Right.

Dr. HSIANG. So those are some of the types of compromises people living on the coast will have to make in the coming years, if the previous trends of emissions continue.

Mr. PANETTA. And that type of fortification, I mean, you can't really apply that across the board, though. That is the thing. I mean there is obviously, you know, geographical limitations. And I can tell you, in my district there would probably be a lot of political limitations about obstructing a seawall along a scenic drive in Carmel, California.

But, you know, what—you know, in regards to that type of fortification, I mean, where do you see that being appropriately done?

Dr. HSIANG. That is a very open field of research. There are a lot of individuals trying to understand what would be the types of cost-effective adaptations that the government or local communities ought to deploy, and a fair amount of it is going to be individuals actually investing their own private resources in trying to protect their own home.

But, of course, in the case of something like a seawall, if I build one in front of my home, and my next-door neighbor chooses to not invest quite as much money in theirs, then I am now subject to risk based on their choices.

Mr. PANETTA. Right.

Dr. HSIANG. And so this is going to create a situation in which we now have to negotiate over these types of adaptations. We are going to spend money on those negotiations. We are going to spend our, like, sort of our patience with one another on those types of conversations, instead of focusing on how to make the schools better, instead of focusing on other things that we like to invest in, as a community.

Mr. PANETTA. And let's say—you know, obviously, you mentioned private investment. What are we talking in public investment? How much is the government—and Mr. Gómez might have an answer for this.

How much of these types of costs are going to be undertaken by the U.S. Government when it comes to this type of fortification?

Mr. GÓMEZ. Sure. So in the area of coastal property damages, you know, we—again, our role is to provide Congress with information in terms of where those exposures are.

And currently, in the federal government, it is through the National Flood Insurance Program. I mean that is a program that owes the Treasury $21 billion, currently. And the program was never really set up to take care of all the expenses and losses. We have made recommendations that Congress should also make structural changes in that program, so that it can send clear signals to the folks that are buying insurance. That is just one example.

I also wanted to mention—because earlier we were talking about communities that are at risk. And one set of communities that we haven't talked about where we see the impacts already taking place, and that is Alaska Native communities. They live on the coast and on rivers. So GAO has a body of work, we have looked at those communities, looked at what federal programs are available to help them retreat, but to help them adapt to those changes.
Mr. Panetta. My time has expired. Thank you again for being here.

Thank you, Mr. Chairman.

Chairman Yarmuth. The gentleman’s time has expired. And I will mention for the record that the Pebble Beach Golf Course, where the U.S. Open is being held this week, actually fortified the 18th fairway, because of the sea, as well. You know where my head is at this week.

So I now yield myself 10 minutes. I want to follow up on what my good friend, Mr. Woodall, was talking about, because the reason that we wanted to do this hearing was because we believe that there are things that we need to look forward at, and anticipate what policy consequences might ensue from an analysis of what the costs of certain things are—climate change certainly being an important one.

We are going to have a hearing on immigration policy, as well, as to what the financial impact—what the consequences for the taxpayer will be, moving forward.

We are going to have a hearing at some point on artificial intelligence, and what that is going to mean for the budget and the taxpayers, because I think it is going to be the most disruptive force in—probably in the history of the world, moving forward.

And the idea behind these hearings is not really to convince anybody of any policy preference or any philosophical argument. It is just to get information.

And unfortunately, I think what you see sometimes—I saw it today on both sides—is that there is less of a governing mentality in Washington than there is in electoral mentality. And regardless of what the issue is, there is always an attempt to figure out where the electoral advantage lies, or the PR advantage might lie, as opposed to where we can search for an appropriate governing strategy in that particular area. And I know Mr. Woodall is very much committed to that, as am I. And I hope we can influence our colleagues in that direction.

On the subject of the future, I—there was a representative of Microsoft in my district last week. She is the chief technology officer of Microsoft. And she was there because they are entering into a partnership with our community in terms of developing it higher—a better tech community, and getting more tech jobs. She made a statement which I found absolutely astounding. She said that, in the next 10 years, we will experience 250 years of change. Think about that, that in the next 10 years we will experience as much change as we have experienced since the founding of the country.

And so, when I think of the opportunity for technology to develop to help us both adapt and to mitigate climate change, I am reassured by those—that projection, even though I am sure there is a plus or minus 150 years in that assessment. But this leads to a question I have of Dr. Hayhoe.

You talked about loading the dice. And essentially, that is what we are doing right now, is rolling the dice, because you have got different assessments; Dr. Cass, you have different assessments where the impact may be. And we know there is a considerable amount of variation as to what that might be.
But the costs of being wrong are pretty dramatic. Is that the point you were trying to make?

Dr. Hayhoe. Yes. The world is changing very quickly. And our civilization is built on the assumption of a stable climate. Our agriculture, our water, the allocation of our energy resources, even our economics and our international policies are all built on the assumption that climate is stable, as it has been over the history of human civilization.

Today it is changing faster than that. And the best analogy I have is actually from west Texas. So it is very flat there, and we have a lot of dead, straight roads. And you can get down the road staying in your own lane, looking in the rearview mirror, because where you were five minutes ago is a perfect predictor of the future. But when you hit a curve, you have to take your eyes off the rearview mirror, and you have to look ahead, because if we do not do that we will not make it around the curve safely. And we are facing and are already on the largest curve we have experienced, climatically speaking, in the history of human civilization, and our wheels are already on the rumble strip.

Chairman Yarmuth. I appreciate the metaphor.

Dr. Hsiang, I know Mr. Crenshaw asked you a question, and it was a rhetorical one, because he didn’t want you to answer, but I would like you to elaborate on this question of the health impacts, whether it is mental health or otherwise. How exactly—just walk that—walk through us why there would be more suicides, why there would be damage to fetuses, why the crime rate would go up as a result of these climate changes?

Dr. Hsiang. Thank you. Thank you for giving me the chance to revisit this issue.

There is a variety of ways in which environmental conditions affect human health. We all know that we get less comfortable when it is hot. And part of that is because our body is actually experiencing difficulty functioning at higher temperatures, and it is actually making you uncomfortable, trying to incentivize you to go somewhere safer.

We see, for example, on extremely hot days, increases in cardiovascular mortality rates, largely due to people trying to—their hearts have to work harder to move more blood to the surface of your skin to cool your body down. This is a very serious issue, and there are different discussions about how much we have adapted to this in the past. In fact, a lot of the numbers that were discussed earlier were completely consistent with the rates of mortality we see on hot days in U.S. counties right now, today.

There is other types of vector-borne disease. There is projections about mosquitos traveling much further north and surviving for much longer periods of time, as temperatures warm. And, in particular, humidity rises. So our projections indicate that humidity in, you know, the Northeast, in New England in the future, in the next 80 years, could easily feel like humidity in Louisianna today. Okay? That is a completely different world, from a human health standpoint.

When you think about fetuses, what we have observed using Census data—my colleague, Reed Walker, has done some fascinating research, where you actually see—if a pregnant mother is
exposed to a very hot day, we actually can see that by tracing that child over time in their earnings 30 years later. So a child born the year before on the exact same day, or the year after on the exact same day, but when they were not—their mother was not exposed to a heat wave, they are actually earning more for multiple decades into the future. Now, we don’t know exactly what the mechanism is. But what people think is happening is that the stress of the mother is affecting the development of the child that she is carrying.

The last question you are asking is about mental health and crime. And this is actually—you know, calling it ridiculous is something that I can understand when you first hear these facts. But actually, in law enforcement, for example, it is well known and understood that on extremely hot days violent rates go up. And so police departments everywhere actually adapt today by deploying more police forces to cope with this very human response.

Now, we don’t know exactly what is happening, and why people change their behavior. But it is, in my experience, for—looking at this type of data for over a decade, one of perhaps the single-most robust statistical facts. Anyone in the world can look at their data. You can look at any state, any city, and you see that, as the temperatures rise, levels of interpersonal violence go up.

And now, in our latest study over the last year, we showed that people perpetrating violence against themselves. Self-harm and suicide rates are incredibly responsive to temperature. In fact, you can look almost anywhere in the world and see this relationship. We don’t understand exactly why it occurs, but it is the type of thing that is not going away, as air conditioning is deployed across the country. We actually see that this relationship is getting tighter and stronger over time. And in fact, it is occurring most strongly in the wealthiest communities in the United States.

Chairman YARMUTH. Thank you.

Mr. Gómez, I think Mr. Panetta asked about budgeting, the issue of budgeting at federal agencies for costs of disasters. Is that a good idea? And how would you do it?

Mr. GÓMEZ. So again, I think I mentioned earlier that one way is to provide you all with information that you can use, that gives you information on those programs across the federal government that are exposed to a high fiscal exposure, so that you can make those trade-offs.

And so—but one other thing that I wanted to mention that is really important, from a federal perspective, and actually that affects all levels of government and the private sector, and that is that we have recommended in the past that we create a climate information system that provides authoritative climate information that then—that has information on observations and projections that can be updated on a regular basis. And then to have a non-government entity be able to translate that information for all users, for local government, state government, private-sector folks.

As you know, we spend, from a budget perspective—we give billions of dollars a year around the country to build infrastructure. And it is those local folks, decision-makers, state decision-makers, that are having to plan and construct these things. And they are
telling us that they need better information, forward-looking cli-
mate information, so they can build these things with resilience.
So I think, from a budget perspective, that is where we can save
money in the long run.
Chairman YARMUTH. Well, I thank you for your answer. I thank
all four of you for your testimony and your responses. I think it has
been a fascinating hearing. And I appreciate your participation
very much, and your work.
And with that, with no objection, the meeting is—the hearing is
adjourned.
[Whereupon, at 12:25 p.m., the Committee was adjourned.]
CONGRESSWOMAN SHEILA JACKSON LEE OF TEXAS

STATEMENT

HEARING:

"COSTS OF CLIMATE CHANGE:
RISKS TO U.S. ECONOMY AND FEDERAL BUDGET"

COMMITTEE ON THE BUDGET

210 CANNON

JUNE 11, 2019

10:00 A.M.

Thank you Chairman Yarmuth and Ranking Member Womack for convening this hearing to explore the domestic economic consequences of climate change across regions and sectors and highlight the current and long-term fiscal risks to the Federal government if action is not taken to mitigate and adapt to the changing climate.

Let me welcome our witnesses:

Katharine Hayhoe, Ph.D.
Professor and Director of the Climate Science Center
Texas Tech University
Solomon Hsiang, Ph.D.
Professor and Director of the Global Policy Laboratory
University of California, Berkeley
Visiting Scholar at Stanford University

J. Alfredo Gómez
Director, Natural Resources and Environment
U.S. Government Accountability Office

Oren Cass (Republican Witness)
Senior Fellow
Manhattan Institute

- Thank you for being here and sharing your expertise with this Committee.

- Mr. Chairman, climate change is not a figment of our imagination or a hoax perpetrated by the Government of China; it is real.

- The fundamental science is clear, compelling, unassailable, and supported by a large body of research and real-world observations.

- For example, the Fourth National Climate Assessment provided an extensive, science-based, and expert-reviewed description of the current state of the science.

- Among the most salient conclusions of the Assessment are:

  1. “High temperature extremes and heavy precipitation events are increasing. Glaciers and snow cover are shrinking, and sea ice is retreating. Seas are warming, rising, and becoming more acidic, and marine species are moving to new locations toward cooler waters. Flooding is becoming more frequent along the U.S. coastline. Growing seasons are lengthening, and wildfires are increasing.”
2. “In the absence of more significant global mitigation [and regional adaptation] efforts, climate change is projected to impose substantial damages on the U.S. economy, human health, and the environment. Under scenarios with high emissions and limited or no adaptation, annual losses in some sectors are estimated to grow to hundreds of billions of dollars by the end of the century. It is very likely that some physical and ecological impacts will be irreversible for thousands of years, while others will be permanent.”

- In other words, Mr. Chairman, to borrow a line made famous by former President Bill Clinton, “if we don’t deal with [climate change], it will surely deal with us.”

- Just consider these facts.

- Global average temperature increased by about 1.8°F from 1901 to 2016 and increases ranging from 3°F to 12°F (1.6°–6.6°C) are expected by the end of century, depending on progress toward significantly reducing greenhouse gas emissions.

- Sea level has increased by about 9 inches since the early 20th century, increasing the frequency of high tide flooding by a factor of 5 to 10 for several U.S. coastal communities.

- Sea level is very likely to rise another 1 to 4 feet by the end of the century, putting nearly 2.5 million coastal properties, valued at over $1 trillion today, at risk of chronic flooding.

- The median risk of commercial properties being hit by a category 4 or 5 hurricane has increased by 137 percent since 1980, and this increase could rise further to 275 percent by 2050.

- During the summer of 2015, over 10.1 million acres—an area larger than the entire state of Maryland—burned across the United States,
surpassing 2006 for the highest annual total of U.S. acreage burned since record keeping began in 1960.

- If we continue business as usual with high emissions and limited resilience efforts, climate-related losses will likely grow to exceed roughly 3 percent of national GDP, or about $500 billion annually, by the end of the century.

- More than 10,000 additional lives, and almost two billion labor hours costing an estimated $160 billion in lost wages, could be lost annually by 2090 due to temperature extremes.

- By the late 21st century, the poorest third of U.S. counties could experience damages due to climate change of up to 20 percent of total personal income, compared with 7 percent for the wealthiest counties.

- Over the last 3 years, the United States has experienced disaster costs exceeding $150 billion per year, compared with approximately $16 billion per year (inflation-adjusted) 30 years ago.

- Growth in federal spending on hurricane relief and recovery is projected to increase 33 percent faster than the economy by 2075.

- Roughly two-thirds of DOD’s 79 mission assurance priority installations are vulnerable to climate change.

- The net additional cost of transitioning to a clean energy economy and reducing emissions by 80 percent by 2050 would likely range from zero to 0.8 percent of GDP.

- The costs for solar energy and onshore wind have fallen by 84 percent and 49 percent, respectively, just since 2010.

- Doing nothing is simply not an option because as has been documented in several highly regarded studies, the economic
damages wrought by climate change will be large, span across industries, and put every region at risk, especially for the poorest and most vulnerable.

- Additionally, climate change will increase costs in multiple ways across many federal programs, including the following:
  
  1. Disaster relief and recovery
  2. Federal insurance programs
  3. Federal facilities and federally managed lands, infrastructure, and waterways

- The Congressional Budget Office (CBO) has estimated that the growth in federal spending on hurricane relief and recovery would increase 33 percent faster than the economy by 2075, and nearly half of this increase is attributable to climate change.

- Flood insurance and flood prevention costs will grow due to increased coastal and inland flooding and crop insurance costs will grow by at least 40 percent by 2080 due to decreasing agricultural yield and increasing variability – all due to climate change, according to Obama Administration estimates.

- The federal government owns more than 775,000 buildings and structures with a total estimated replacement cost of nearly $2 trillion.

- Of these amounts, the Department of Defense owns and operates more than two-thirds of the buildings and structures and 28 million acres of land, with an estimated replacement value of approximately $1 trillion.

- To put the Defense Department’s operational exposure to climate risks in perspective, consider that approximately two-thirds of 79 DoD mission assurance priority installations are vulnerable to climate change, especially from flooding, drought, and wildfires.
• So, thank you, Mr. Chairman, for convening this important hearing on the costs of climate change and the damage it will inflict on the national economy and federal budget if we fail to meet this pressing issue of our time.

• Thank you, I yield back the remainder of my time.
Questions for All Witnesses

During the hearing, Congressman Rob Woodall (R-GA) asked the witnesses if they could verify the data presented by Mr. Cass showing that the Environmental Protection Agency (EPA) has projected temperature-related mortality rates in 2100 for northern cities to be 50 to 75 times higher than in 2000 for southern cities, specifically: “Is double digits right on the one hand and fractional digits right on the other?”

The referenced chart showed bars from the left to right with the following values for “Estimated net mortality from extremely hot and cold days (deaths per 100,000 residents)”:  
- Phoenix (2000): 0.17  
- Houston (2000): 0.16  
- New Orleans (2000): 0.21  
- Pittsburgh (2100): 12.83  
- Detroit (2100): 9.19  
- New York (2100): 8.92

1. According to the Climate Action Benefits Report published by the EPA (Mr. Cass provided a direct link in his published report: https://www.epa.gov/cira/climate-action-benefits-extreme-temperatures), did the study estimate temperature-related mortality using a model that projected mortality rates for some northern cities in 2100 to be as much as 50 to 75 times higher than for some southern cities in 2000, as depicted in the chart shown during the hearing?

2. Do you consider this to be a plausible estimate of the impact of climate change?

Questions for Dr. Solomon Hsiang

1. In speaking to the New York Times about Hsiang et al., 2017, “Estimating economic damage from climate change in the United States,” you explained the finding that the warmest counties will be in states that already have warm climates by saying, “The reason for that is fairly well understood: A rise in temperatures is a lot more damaging if you’re living in a place that’s already hot.”
Do you stand by that statement or, per your conclusion in the 2018 working paper, “Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits,” is it now your view that such places “are currently so heavily adapted to hot climates that their response functions are already relatively shallow at the hot end, so additional warming leads to limited additional mortality or adaptation costs — these locations then end up benefiting from reductions [in] a relatively small number of cold days.”

2. Between Hsiang et al., 2017 and the 2018 working paper, which do you believe provides a more plausible estimate of the mortality-related effects of climate change for the United States and why?
Question for the Record

Dr. Hsiang, thank you for your testimony and for your work with the Climate Impact Lab. Understanding climate change’s impact on all aspects of our lives, including human health and our economy, is the first step in increasing individual and community resilience and I applaud your efforts.

The Fourth National Climate Assessment highlights the unique occupational risks and decreasing productivity workers across the United States, including agricultural workers and watermen in the southeastern United States, will face as the climate changes. I appreciated your testimony focused on how workers and households have adapted to climate impacts in the past and the varying levels of success they achieved.

Given the uncertainty about how climate change will impact the health and productivity of workers across diverse industries and regions, what do you recommend Congress do today — while we also work to mitigate emissions and global climate change — to increase occupational safety and make industries more resilient moving forward?
“The Costs of Climate Change: Risks to the U.S. Economy and the Federal Budget”
June 11, 2019
Questions for the Record
Ranking Member Steve Womack

Questions for All Witnesses

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GAO Response: The numbers above appear to reflect the numbers reported by EPA in 2015, based on data provided on EPA's website (https://www.epa.gov/sites/production/files/2015-06/extreme-temp-fg-1.cvs) for "Projected Extreme Temperature Mortality in Select Cities Due to Unmitigated Climate Change."

2. Do you consider this to be a plausible estimate of the impact of climate change?

GAO Response: In September 2017, GAO reported on the methods used to estimate the potential economic effects of climate change in the United States, among other things.1 We found that these methods, including those used in the EPA study referenced above, are based on developing research and produce imprecise information because of information and modeling limitations such as (1) climate modeling uncertainty; (2) limited information on which to base models for specific economic sectors; (3) incomplete coverage of sectors, interactions among sectors, and climate change impacts; and (4) challenges of modeling over long time frames. EPA officials associated with the study told us that the complex models used in these methods are not meant to provide "precise" estimates. They said that models provide an

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indication of direction and relative magnitudes and should be considered as one tool among many in the policymaker’s toolbox.

We also reported that even though the methods used to estimate the potential economic effects of climate change produce imprecise results, they can convey useful insight into broad themes about potential climate damages across sectors in the United States, according to several experts we interviewed. For example, experts told us that these methods can provide valuable research information about the potential magnitude of economic effects and potential areas of greatest concern.
“The Costs of Climate Change: Risks to the U.S. Economy and the Federal Budget”

June 11, 2019

Questions for the Record

Ranking Member Steve Womack

Responses by Oren Cass, Senior Fellow, Manhattan Institute
July 25, 2019

1. Yes, I believe that is a correct interpretation of the study.

2. No, I do not consider it to be a plausible estimate.

Response to Questions by Ranking Member Steve Womack

Questions for all Witnesses

1. According to the Climate Action Benefits Report published by the EPA, did the Study estimate temperature-related mortality using a model that projected mortality rates for some northern cities in 2000 to be as much as 80-95 times higher than for some southern cities in 2000, as depicted in the chart shown during the hearing?

Reply: Yes, the report used the peer-reviewed results from the study by Mills et al (Climate Change, 2013). Those results do project mortality rates in some northern cities in 2000 to be on the order of 30-75 times higher than some southern cities in 2000.

2. Do you consider this to be a plausible estimate of the impact of climate change?

Reply: My team’s own research suggests mortality estimates could be substantially different than those presented by Mills et al. Such differences often emerge in science, and are most usefully understood by inspecting the source of those differences.

As highlighted by Ranking Member Womack, the EPA report estimates that mortality rates in Pittsburgh, PA may increase from 0.36/100,000 to 12.85/100,000 between 2000 and 2060. For Detroit, MI the corresponding change is 0.7/100,000 to 9.19/100,000 and for New York, NY it is 0.41/100,000 to 8.9/100,000. These represent increases of 12.4, 8.49, and 8.52 per 100,000 for these three northern cities. In contrast, one of our analyses that uses a comparable method (Huang et al, Science 2017) estimates that warming during the same period would alter mortality rates in Allegheny County, PA (containing Pittsburgh) by 3/100,000, in Wayne County, MI (containing Detroit) by 24.7/100,000, and in New York County, NY by 51.5/100,000. For all three northern cities, we estimate changes in mortality much smaller than those contained in the report. In fact, for two of these cities, we estimate that warming will reduce all-cause mortality on average.

Overall, these study fellow similar methods, but there is a clear reason why the two analyses reach different conclusions. The EPA report draws on projections presented in Mills et al (Climate Change, 2013). Mills et al., in turn, draws on results from a study by Medina-Ramon & Schwartz (Occupational and Environmental Medicine, 2007) which estimated the effect of hot and cold days on all-cause mortality using standard statistical approaches. Medina-Ramon & Schwartz found that all-cause mortality increased by 0.04% per degree Celsius of extreme cold exposure in the current and prior day. All-cause mortality increased by 0.32% per degree Celsius of extreme heat exposure in the current and prior day. The quantitative difference between effects of
extreme cold and extreme heat indicate that warming is deadlier than cooling, and this gives rise to the difference between the two studies.

Because the results of Medina Ramon & Schwartz suggest that extreme cold is less deadly than extreme heat in the short run, simulations of climate change in Mills et al. find that rising temperatures are extremely harmful to northern cities. This is because these cities suffer additional excess mortality in response to the rising number of future hot days. However, because cold temperatures are not estimated to be harmful, rising temperatures in projections by Mills et al. do not result in substantial benefits to health resulting from the reduction in the number of cold days.

However, the large asymmetry in the effect of hot and cold days, as estimated by Medina Ramon & Schwartz, is now understood to not reflect the entire impact of changing temperatures. In a later analysis by Deschênes and Moretto (The Review of Economics and Statistics, 2009), it was shown that the impacts of extreme cold manifest in excess mortality over a longer time horizon than was accounted for in Medina Ramon & Schwartz. Specifically, Deschênes and Moretto found that excess mortality from extreme cold in the US occurs for up to thirty days after a cold weather event, with the vast bulk of this effect delayed beyond the two days considered by Medina Ramon & Schwartz. In contrast, Deschênes and Moretto report that excess mortality from extreme heat occurs primarily in the first three days after the heat event, so much of this effect was originally accounted for in the analysis of Medina Ramon & Schwartz.

Because the Mills et al. used the older analysis by Medina Ramon & Schwartz, which did not account for the delayed mortality effects of cold days, they over-estimate the mortality damage from warming that would be expected in northern cities. Had they accounted for these effects, they would have recovered smaller mortality estimates more similar to those presented in Hsiang et al., which used results from Deschênes and Moretto and other more recent studies to inform the analysis. This difference highlights the importance of using the most up-to-date and best available scientific research when estimating the costs the economic consequences of climate change.

Questions for Dr. Solomon Hsiang

1. In speaking to the NYT about Hsiang et al. 2017, you explained that the finding that the worst-hit counties will be in states that already have warm climates by saying, “The reason for that is fairly well understood: A rise in temperature is a lot more damaging if you’re living in a place that is already hot.” Do you stand by that statement, or, per your conclusions in the 2018 working paper, “Tailoring the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits,” is it now your view that such places “are currently so heavily adapted to hot climates that their response functions are already relatively shallow at the hot end, so additional warming leads to limited additional mortality or adaptation costs – these locations then end up benefiting from the reductions in [n] a relatively small number of cold days.”

Reply: These statements do not necessarily contradict one another, and I stand by both statements, since they are both correct. Figure 1 below shows results from Hsiang et al. (Science, 2017) and Figure 2 shows the most recent results for the referenced working paper, Carleton et al. (NBER, 2020). In the first analysis, which did not model changes in future adaptation, we found that hot locations were most adversely affected. In the second analysis, we found the same pattern largely held, with exceptions in a small number of the hottest counties in southern tips of Florida and Texas. In these locations, the second quote described above applies.

2. Between Hsiang et al. 2017 and the 2018 working paper, which do you believe provides a more plausible estimate of the mortality-related effects of climate change in the United States and why?
Reply. The 2020 update to the working paper presents the most plausible estimates. It accounts for population growth, income growth, adaptation costs, and adaptation benefits, all of which were explicitly omitted from the earlier 2017 publication.

Figure 1: Mortality effects of climate change presented in Hsiang et al (Science, 2017), as shown in Figure S2, for 2080-2099 in RCP 8.5.

Figure 2: Mortality effects of climate change presented in Carleton et al (NBER, 2020), as shown in Figure B (reproduced here using a different color scheme), for 2080-2099 in RCP 8.5.
Response to Questions by Representative Robert C. Scott

1. Given the uncertainty about how climate change will impact the health and productivity of workers across diverse industries and regions, what do you recommend Congress do today—while we also work to mitigate emissions and global climate change—to increase occupational safety and make industries more resilient moving forward?

Repl. Congress can increase occupational safety by strengthening protections to workers who are exposed to extreme temperatures. Currently, NIOSH simply provides recommendations for workplace temperatures without ensuring that guidance is followed or that workers are not exposed to hazardous thermal conditions. At present, workers sometimes are only able to protect themselves by reducing the intensity of their effort or stopping work. Encouraging investments in climate-related protections, such as air conditioning systems for warehouses and factories, will both protect workers and make their industries more resilient. Our research indicates that these investments are often not undertaken because they appear too expensive to firms or because firms do not realize the long-term economic benefit of these investments. It is possible that grants or loans that reduce the cost of such investments will increase their uptake. Building codes could also be updated to ensure thermal protection of workers. Alternatively, employers could be required to provide hazard pay for workers exposed to extreme climate conditions. Any of these approaches would protect workers while making industries more resilient. As its core, the issue is that workers bear the cost of extreme climate conditions, and employers are not incentivized to reduce their exposure in industries where workers have limited bargaining power. In such situations, policy can be used to ensure that both workers and employers share in the effort to protect workers from thermal extremes. Better protected workers will be more productive and less susceptible to climate change and climate variability, resulting in industries becoming more resilient.

Thank you,

Solomon Hsiang
Chancellor’s Professor of Public Policy
Director of the Global Policy Laboratory
University of California, Berkeley

Co-Director
Climate Impact Lab
Research Associate
National Bureau of Economic Research
QUESTIONs FOR ALL WITNESSES — Responses by K. Hayhoe

Q: According to the Climate Action Benefits Report published by the EPA, did the study estimate temperature-related mortality using a model that projected mortality rates for some northern cities in 2100 to be as much as 50 to 75 times higher than for some southern cities in 2000, as depicted in the chart shown during the hearing?

A: If one uses the link provided by Mr. Cass one can click through to the following document: https://www.epa.gov/sites/production/files/2015-06/documents/extremetemperature.pdf which contains the following figures:

The figure on the left shows projected mortality rate, in units of deaths per 100,000 people, for 49 cities under a future scenario of unmitigated climate change. The figure on the right shows the same indicator but under a scenario of global greenhouse gas mitigation.

The statement in the question compares the size of the dots in either the “Reference-2100” or the “Mitigation-2100” map (Figure 1, lower right or Figure 2, lower right) to the “Baseline-2000” map (Figure 1 and Figure 2, left).

Since the question is whether the estimate of northern cities in 2100 being 50-70 times higher than southern cities in 2000 is accurate, and the changes projected under the “Reference-2100” scenario are larger, my analysis will focus on comparing the “Reference-2100” and “Baseline-2000” maps.

It is important to note that the actual data shown in these figures is required to fully respond to the question. From this figure it is only possible to estimate the increases based on the figure legend. However, we can see that:

- The difference between the mortality rates in the legend ranges from 0-2 up to 15-18 per 100,000 people
In 2000, many cities—in both the north and the south—fall into the 0-2 category. In 2100, as far as it is possible to tell from this figure, it does not appear that any northern cities fall into the 15-18 category; therefore the largest possible “Reference-2100” mortality rate for cities in the Midwest and Northeast is 14 and in actual fact the value for such cities could range from 11 to 14.

To obtain an increase of 50 to 70 times with a maximum value of 14, one would need to be comparing a southern city with 0.2 (14/70) to 0.28 (14/50) deaths per 100,000 in 2000 with a northern city with 14 deaths per 100,000 in 2100.

Quantitative mortality rates for 2100 by city are not available from either this document or from Mills et al. (2014). The full citation for this publication is:


However, in “Online Resource 3” available at: https://link.springer.com/article/10.1007/s10584-014-1154-8#additional-information, Mills et al. (2014) have a table summarizing 2000 total mortality rates by city. Combining this information with the future maximum northern city range of 11-14 deaths per 100,000 shown in Figure 1 above, it is possible to determine whether there are any southern cities with a 2000 mortality rate that is 50 to 70 times smaller than a northern city in 2100. The original table from Mills et al. (2014) is included at the end of this response.

I reviewed Mills’ table and identified all the southern cities with less than 10 heat-related deaths in 2000. These cities and their 2000 deaths are listed in columns 1 and 2 below. I then added population from 2000 according to the U.S. Census (column 3 in the table below). I divided column 2 by column 3 and multiplied by 100,000 to get the number of heat-related deaths per 100k in 2000 (column 4). Finally, I divided 11 and 14, the minimum and maximum mortality rate per 100k for a northern city under the “Reference-2100” scenario, by column 4 to get the projected change by 2100 for a northern city compared to each southern city (columns 5 and 6).

<table>
<thead>
<tr>
<th>City</th>
<th>2000 Heat-Related Mortality (total)</th>
<th>2000 Population</th>
<th>2000 Heat-Related Mortality (per 100k)</th>
<th>Change compared to 11 per 100k*</th>
<th>Change compared to 14 per 100k**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albuquerque, NM</td>
<td>5</td>
<td>448,386</td>
<td>1.12</td>
<td>9.9</td>
<td>12.6</td>
</tr>
<tr>
<td>Austin, TX</td>
<td>5</td>
<td>672,963</td>
<td>0.74</td>
<td>14.8</td>
<td>18.8</td>
</tr>
<tr>
<td>Birmingham, AL</td>
<td>4</td>
<td>242,216</td>
<td>1.65</td>
<td>6.7</td>
<td>8.5</td>
</tr>
<tr>
<td>Charlotte, NC</td>
<td>1</td>
<td>571,382</td>
<td>0.18</td>
<td>62.9</td>
<td>80</td>
</tr>
<tr>
<td>Greensboro, NC</td>
<td>1</td>
<td>246,640</td>
<td>0.42</td>
<td>26.0</td>
<td>33.1</td>
</tr>
<tr>
<td>New Orleans, LA</td>
<td>0</td>
<td>484,668</td>
<td>N/A</td>
<td>Inf.</td>
<td>Inf.</td>
</tr>
<tr>
<td>Oklahoma City, OK</td>
<td>6</td>
<td>506,673</td>
<td>1.18</td>
<td>9.3</td>
<td>11.8</td>
</tr>
<tr>
<td>Tulsa, OK</td>
<td>3</td>
<td>393,124</td>
<td>0.76</td>
<td>14.4</td>
<td>18.3</td>
</tr>
</tbody>
</table>

* This is the lowest possible value for a northern city with an increase in the range of 11-14 in Figure 1
** This is the highest possible value for a northern city under the “Reference-2100” scenario according to Figure 1
Recall that to obtain an increase of 50 to 70 times with a maximum value of 14, one would need to be comparing a city with 0.2 to 0.28 deaths per 100,000 in 2000 with one with 14 deaths per 100,000 in 2100.

According to my calculations summarized in the table above, there is only one city (Charlotte NC) on the list of cities for which Mills et al. (2014) provide data that has a 2000 value of less than 0.28 deaths per 100,000 — literally, one death in 2000 — and therefore yields an increase that is larger than 20 times that of the largest northern cities in 2100. All other comparisons between the lowest southern cities in 2000 and highest northern cities in 2100 yield increases ranging from 8.5 to 18.8 times 2000 values. Furthermore, Charlotte only has 1 death estimated for 2000; this is an insufficient sample from which to draw any firm conclusions. Rather, the only accurate conclusion is the following, appropriately caveated:

“When the seven southern cities in Mills et al. (2014) with the lowest mortality rates per 100,000 in 2000 are compared with the northern cities with the highest mortality rates per 100,000 under the Reference-2100 scenario, the median increase in mortality rates from 2000 to 2100 ranges from about 14 to 18.”

Based on my analysis I cannot find support for the claim that the EPA’s analysis uses “a model that projected mortality rates for some northern cities in 2100 to be as much as 50 to 75 times higher than for some southern cities in 2000.” Rather, I find that for one city, with one death in 2000, the range could be from 63 to 80 times larger than some northern cities.

Furthermore, calculating a change in relative units starting with a value below 1, as Mr. Cass did, rather than using absolute units as the EPA CIRA analysis did, is an approach that yields large but relatively meaningless factors.

As an analogy, it would be similar to saying a mother, age 30, is 360 times older than her one-month-old newborn — or 10,958 times older than her one-day-old infant — when what actually matters is their absolute age. There is no reason for such a comparison unless the goal is to deliberately emphasize the difference in the two ages (or the two morality rates).

It is important to note that the supplementary material in Mills et al. (2014) does not contain mortality rates for all 49 cities used in the EPA analysis, so there may be some other cities in Figure 1 with 2000 mortality rates below 0.26 per 100,000. However, based on the information available in these maps and the supplementary material, I would conclude that while it is possible that Mr. Cass’ statement may be true for a very small number of cities, this would only be the case if it were made in reference to Charlotte NC or possibly (if there are more low-2000-mortality southern cities in the full dataset of 49) a small handful of cities with less than 0.2 to 0.26 deaths per 100,000 in 2000 (representing a total of perhaps less than 10 actual deaths total, an unrealistically small sample size from which to draw conclusions) to compare to cities 100 years in the future.

MILLS TABLE (with southern cities with less than 10 heat-related deaths in 2000 highlighted):
Online Resource 3. Projected mortality from extremely hot and extremely cold days in study locations under modeled climate conditions for the baseline year 2000 period

<table>
<thead>
<tr>
<th>City</th>
<th>Year 2000 modeled base year</th>
<th>Cold</th>
<th>Hot</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albuquerque, NM</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Atlanta, GA</td>
<td>10</td>
<td>21</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Austin, TX</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Baltimore, MD</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Birmingham, AL</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Boston, MA</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Canton, OH</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Charlotte, NC</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Chicago, IL</td>
<td>7</td>
<td>91</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>Cincinnati, OH</td>
<td>1</td>
<td>33</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Cleveland, OH</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Columbus, OH</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Dallas, TX</td>
<td>6</td>
<td>35</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Detroit, MI</td>
<td>3</td>
<td>25</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Greensboro, NC</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Houston, TX</td>
<td>9</td>
<td>10</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Kansas City, MO-KS</td>
<td>0</td>
<td>71</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>Milwaukee, WI</td>
<td>1</td>
<td>16</td>
<td>17</td>
<td></td>
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<tr>
<td>Minneapolis, MN</td>
<td>1</td>
<td>25</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Nashville, TN</td>
<td>0</td>
<td>24</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>New Haven, CT</td>
<td>1</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>New Orleans, LA</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>New York City/Jersey City, NY-NJ</td>
<td>10</td>
<td>75</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Oklahoma City, OK</td>
<td>0</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Philadelphia, PA</td>
<td>3</td>
<td>13</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Pittsburgh, PA</td>
<td>0</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Provo, UT</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Salt Lake City, UT</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>St. Louis, MO</td>
<td>0</td>
<td>27</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Terre Haute, IN</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Tulsa, OK</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
Online Resource 3. Projected mortality from extremely hot and extremely cold days in study locations under modeled climate conditions for the baseline year 2000 period

<table>
<thead>
<tr>
<th>City</th>
<th>Year 2000 modeled base year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cold</td>
</tr>
<tr>
<td>Washington, DC</td>
<td>1</td>
</tr>
<tr>
<td>Youngstown, OH</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>72</td>
</tr>
</tbody>
</table>
* Totals may differ from the sum of the results for the different types of days as a result of rounding values for presentation.

Q: Do you consider this to be a plausible estimate of the impact of climate change?

According to the Fourth U.S. National Climate Assessment, extreme heat is projected to become more frequent in the future (very high confidence).

“Extreme temperatures in the contiguous United States are projected to increase even more than average temperatures. The temperatures of extremely cold days and extremely warm days are both expected to increase. Cold waves are projected to become less intense while heat waves will become more intense. The number of days below freezing is projected to decline while the number above 90°F will rise. (Very high confidence)” (Volume 1, Chapter 6, Vose et al. 2017)

According to the U.S. Global Change Research Program’s Climate and Health Assessment (2016), heat-related deaths are projected to increase (very likely, high confidence) and there will be an increase in population tolerance to extreme heat (very likely, very high confidence).

“Based on present-day sensitivity to heat, an increase of thousands to tens of thousands of premature heat-related deaths in the summer [Very Likely, High Confidence] and a decrease of premature cold-related deaths in the winter [Very Likely, Medium Confidence] are projected each year as a result of climate change by the end of the century. Future adaptation will very likely reduce these impacts (see Changing Tolerance to Extreme Heat Findings).” And “an increase in population tolerance to extreme heat has been observed over time [Very High Confidence]. Changes in this tolerance have been associated with increased use of air conditioning, improved social responses, and/or physiological acclimatization, among other factors [Medium Confidence]. Expected future increases in this tolerance will reduce the projected increase in deaths from heat [Very Likely, Very High Confidence].” (Chapter 2, Sarioff et al. 2016)

The EPA CIRA analysis accounts for both of these factors – increases in extreme heat and increases in population tolerance – when calculating projected increases in extreme heat by city. Specifically, it addresses tolerance, or “temperature adaptation,” using an “analog city” approach. As such, it is my opinion that the estimates it produces are plausible given the state of scientific knowledge at this time.