SOLVING THE CLIMATE CRISIS: DRAWING DOWN CARBON AND BUILDING UP THE AMERICAN ECONOMY

HEARING

BEFORE THE

SELECT COMMITTEE ON THE CLIMATE CRISIS

ONE HUNDRED SIXTEENTH CONGRESS

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SOLVING THE CLIMATE CRISIS: DRAWING DOWN CARBON AND BUILDING UP THE AMERICAN ECONOMY

TUESDAY, APRIL 30, 2019

HOUSE OF REPRESENTATIVES,
SELECT COMMITTEE ON THE CLIMATE CRISIS,
Washington, DC.

The committee met, pursuant to call, at 10:02 a.m., in Room 2247 Rayburn House Office Building, Hon. Kathy Castor [chairwoman of the committee] presiding.

Present: Representatives Castor, Bonamici, Huffman, McEachin, Levin, Casten, Neguse, Graves, Griffith, Palmer, Carter, Miller, and Armstrong.

Ms. CASTOR. Good morning. Welcome to the April 30, 2019 meeting of the Select Committee on the Climate Crisis. The committee will come to order. And without objection, the chair is authorized to declare a recess of the committee at any time.

Today, we will set the table for the select committee's work on the biggest challenge before us: how to decarbonize the economy, in accordance with climate science, while creating family-sustaining jobs and building a more equitable society.

For the benefit of the witnesses, I want to note that members will be coming in and out of the hearing, Mr. Luján is with the Speaker, meeting with the President about infrastructure, and several members are chairing, or trying to fit in multiple hearings. I recognize myself for 5 minutes for an opening statement.

This is the first of many select committee hearings that is focused on solutions to the climate crisis. The need for solutions is increasingly urgent. The first major warning Congress received about the impending climate crisis was in 1988, but the Congress didn't act then. Today, we know that oil companies' own scientists warned them about climate change too. But instead of action, executives chose to tell Congress and the American people to ignore the scientists and that we could afford to wait.

Well now, the climate science is too unequivocal to deny. What is clear from the science and what diverse voices, including many young people across America are telling us every day is that if Congress continues to delay, we lose. If Congress chooses the status quo, we lose. In fact, scientists have told us that the world needs to hit net zero carbon emissions by 2050 to avoid the worst consequences of the climate crisis. Getting there means cutting greenhouse gas pollution 45 percent below 2010 levels by 2030. To get there, and to give ourselves a chance of avoiding the most catastrophic consequences of climate change, we have to cut carbon pollution smartly, and soon. Taking action now gives us the best op-

portunity to transition to a clean energy economy, efficiently and equitably.

We still have time to solve the climate crisis, because we have made some good choices. Raising fuel economy standards, supporting wind and solar jobs, investing in research and development, that is coming to fruition now. America chose to lead the world in the Paris Climate Agreement, an agreement vital to the clean energy jobs and innovations underway in America right now. But every time Congress and the administration choose delay, American families and businesses are asked to pay a higher price, whether it is through climate catastrophes, extreme heat, dirtier air, or higher electric bills. But as daunting as the climate crisis is, we can make choices and rise to the challenge.

Many businesses and communities across America have been leading the way. More than 3 million Americans work in the clean energy economy, existing energy efficiency standards will save consumers and businesses $2 trillion on utility bills by 2030, and fuel economy standards will save the average household another $2,800 a year at the pump.

Still, there is no substitute for bold Federal policy initiatives that meet the scale of the challenge we face. When we choose clear policies with clear goals, businesses innovate; they reduce cost, they put clean technology to work.

Our witnesses today will help us examine and prioritize our policy choices. We are going to look at infrastructure, at deploying more wind and solar, at electrifying home heating and transportation, at cutting the most powerful climate pollutants and more. We are also going to look at funding research and development, and establishing public private partnerships that move technology from the lab to the market. We are going to look at capturing and storing carbon and pulling it out of the atmosphere. But we have to be clear: Technological breakthroughs are not guaranteed. Choosing to invest in innovation doesn't give us an excuse to choose the status quo elsewhere. At the end of the day, technology is just a tool. It is people who will solve the climate crisis.

The clean energy economy employs millions of people, and we can choose policies that will make those jobs family-sustaining jobs. That includes elevating transition for workers in the fossil fuel industry. They deserve a clean energy economy that delivers for them in their communities. We need good and patriotic policies for them, too, and we need climate solutions that work. We have to pursue many options to meet our goals by 2030 and 2050. The one option we don't have anymore is delay. We must choose climate action now.

And at this time, I will yield to my friend and colleague, the ranking member, Mr. Graves, for an opening statement.

Opening Statement (As Prepared for Delivery)
Rep. Kathy Castor (D–FL)
Chair, U.S. House Select Committee on the Climate Crisis
Solving the Climate Crisis: Drawing Down Carbon and Building Up the American Economy
April 30, 2019

This is the first of many Select Committee hearings that is focused on *solutions* to the climate crisis. The need for solutions is increasingly urgent.

The first major warning Congress received about the impending climate crisis was in 1988. But the Congress didn't act then. Today we know that oil companies' own scientists warned them about climate change, too. But instead of action, executives chose to tell Congress and the American people to ignore the scientists . . . and that we could afford to wait.

Now the scientific consensus is too unequivocal to deny. What is clear from the science and what diverse voices, including young people across America, are telling us every day is that if Congress continues to delay, we lose. If Congress chooses the status quo, we lose.

In fact, scientists have told us that the world needs to hit net-zero carbon emissions by 2050 to avoid the worst consequences of the climate crisis. Getting there means cutting greenhouse gas pollution 45 percent below 2010 levels by 2030.

To get there—and to give ourselves a chance of avoiding the most catastrophic consequences of climate change—we have to cut carbon pollution smartly and soon. Taking action *now* gives us the best opportunity to transition to a clean energy economy efficiently and equitably.

We still have time to solve the climate crisis because we've made some good choices: raising fuel economy standards, supporting wind and solar jobs, and investing in research and development that is coming to fruition now. America chose to lead the world in the Paris Climate Agreement, an agreement vital to the clean energy jobs and innovations underway across America now.

But every time Congress and the administration choose delay, American families and business are asked to pay a higher price whether it's through climate catastrophes, extreme heat, dirtier air or higher electric bills.

But as daunting as the climate crisis is, we can make choices and rise to the challenge.

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When we choose clear policies with clear goals, businesses innovate. They reduce costs. They put clean technology to work.

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But we have to be clear: technological breakthroughs are not guaranteed. Choosing to invest in innovation doesn't give us an excuse to choose the status quo elsewhere.

At the end of the day, technology is just a tool. It's *people* who will solve the climate crisis.

The clean energy economy employs millions of people and we can choose policies that will make those jobs family-sustaining jobs.

That includes elevating transition for workers in the fossil fuel industry. They deserve a clean energy economy that delivers for them, in their communities. We need good and patriotic policies for them, too.

And we need climate solutions that work for people who are on the front lines of the climate crisis. That means putting an end to environmental racism and making sure the jobs at the heart of the clean energy economy are accessible to everyone.

We have to pursue many options to meet our goals by 2030 and 2050. The one option we don't have any more is delay. We must choose climate action now.

Mr. GRAVES. Thank you, Madam Chair. I appreciate the opportunity to address the committee. I hope everybody had a fantastic Easter, and welcome back.

Witnesses, I want to thank you all for being here. I apologize, I didn't come tell you hello this morning, but thank you all for submitting testimony. I did have a chance to go through all your testimony, and I appreciate you making the effort to be here today.

Madam Chair, first of all, I want to reiterate what I have talked about in the past: Climate change is real, humans are having a contribution to it. And the congressional districts, like the one that I represent, that Congressman Carter represents, the effects of sea rise and other challenges, are having real impacts on our communities today.

I think that what we have to do moving forward is be very thoughtful, be responsive, and make sure we are bringing people to the table that actually have experience working in these fields, as opposed to folks setting targets, objectives, and goals that lack any degree of science or reality. Importantly, what we have to do is we have to very carefully think about some of these multilateral agreements like Paris, and look at the cumulative effect of them and determine whether or not these truly will provide a global benefit, a global and environmental benefit, or have adverse consequences.

For example, Madam Chair, I think it is important to note that you can look at what the European Climate Action Network determined. They determined that all European countries are currently not, they are not on a trajectory to actually hit their Paris Accord targets, that they would have to triple their efforts today in order to come into compliance with those targets, and that their targets, to begin with, are insufficient.

So let me say that again, the European Union nations are not hitting their targets; they are not on a trajectory to hit their targets, that they would have to triple their efforts and that their targets, to begin with, were insufficient.

Something else that is really important for us to think about, and one of the biggest flaws in the Paris Accord is the fact that you have China that doesn't even have to reduce emissions, doesn't even have to reduce emissions for several years, and is already more than offsetting the impact of emission reductions in the United States.

Now, I also think that it is important to make note of another really important fact: The IEA, the International Energy Agency, in their recent global energy and CO_2 status report, I want to read a quote from it, because we can sit here and continue demonizing the United States, or we can talk facts. In their report they say: In the United States, emission reductions seen in 2017 were reversed. Our emissions reductions were reversed with an increase of 3.1 percent of CO_2 emissions in 2018. You have seen lots of reporting on that. So folks were looking myopically in 2017 and 2018.

Let's actually look even farther back. Despite this increase, emissions in the United States remained around their 1990 levels, 14 percent at 800 metric tons of CO_2 below the peak in 2000. Now, here is the kicker statement: This is the largest absolute decline among all countries since 2000. We have got to stop this ridiculousness of beating up on the United States. We have got to recognize that we are actually doing extraordinary things without mandates requirements that we are doing—experiencing extraordinary reductions in the United States. We have got to stop these utopian concepts like Green New Deal and other things that lack any degree of reality, that lack any input from actual experts in these fields. We have got to realize that the Paris Accord what the China, India

developing country targets. Calling China a developing country is fascinating to me, using entirely different metrics on how they are reducing emissions. All this is doing is resulting in a net adverse impact to our global environment, while undermining the competition, or the competitiveness of the U.S. workforce and the U.S. economy.

Madam Chair, I look forward to working with you, to build upon some of the successes, and also, learning from some of the failures of previous administrations to try and reduce emissions, particularly looking at the impacts of Ms. Miller's district, looking at the impacts of Mr. Griffith's district, of some of these flawed policies, and moving forward in a direction like we are seeing in Louisiana, where we are exporting natural gas to 35 countries today, and resulting in lower emissions.

Mr. Foster, I want to particularly thank you for your thoughtful testimony. I think that you have come across very balanced and being very realistic. I enjoyed reading your testimony, I thought it was very good; Mr. Guith, you as well. I want to thank you all for just being thoughtful and realistic in your testimony. We often have people come in here that just throw out these things that aren't based. And I am not beating up on you all in anyway, but you had a very balanced and thoughtful realistic approach in your testimony, and I do appreciate you being here.

I am over time, so I am going to go ahead and shut up, but I want to thank you all again.

Ms. CASTOR. Thank you very much to the ranking member. The United States of America has been a world leader and we should keep it that way.

Now I want to welcome our witnesses. First, we have Dr. Diana Liverman, who is a Professor of Geography at the University of Arizona. Dr. Liverman served as a lead author for the Intergovernmental Panel on Climate Change's report on limiting warming to 1.5 degrees Celsius. Her research focuses on how climate change affects people, including historically disempowered groups, and how society can adapt to climate change.

Mr. Hal Harvey, here at the end, is CEO of Energy Innovation, an energy and environmental policy firm. Harvey founded the Energy Foundation, and has served on Federal energy panels under the George H.W. Bush and Bill Clinton administrations. In 2018, he received the United Nations' Clean Air and Climate Change Award, and he is the author of two books on energy and climate.

Mr. David Foster is a distinguished associate with the Energy Futures Initiative, a think tank started by energy security former Energy Secretary Ernest Moniz. Foster served as a senior adviser to Secretary Moniz at the Department of Energy, and was the founding executive director of the BlueGreen Alliance, a partnership between unions and environmental organizations. From 1990 to 2006, Foster was director of the U.S. steelworkers district 11, a 13-State region based in Minneapolis, welcome.

And Mr. Christopher Guith is acting president and CEO of the U.S. Chamber of Commerce's Global Energy Institute. Previously, Guith had served as a Deputy Assistant Secretary in the George W. Bush administration, and worked in the offices of Representatives Bob Barr and Tim Murphy.

Without objection, the witnesses' written statements will be made part of the record. With that, we will go to Dr. Liverman, then to Mr. Guith, and then go down the table this way. So without objection, the witnesses' written statements will be part of the record. Dr. Liverman, you are now recognized to give a 5 minute presentation on your testimony. Thank you.

STATEMENTS OF DR. DIANA LIVERMAN, REGENTS PROFESSOR OF GEOGRAPHY AND DEVELOPMENT, UNIVERSITY OF ARIZONA; HAL HARVEY, CEO, ENERGY INNOVATION; DAVID FOSTER, DISTINGUISHED ASSOCIATE, ENERGY FUTURES INITIATIVE; AND CHRISTOPHER GUITH, ACTING PRESIDENT AND CEO, U.S. CHAMBER OF COMMERCE, GLOBAL ENERGY INSTITUTE

STATEMENT OF DIANA LIVERMAN

Dr. LIVERMAN. Thank you, Chairwoman Castor, Ranking Member Graves, and distinguished members of the committee. Good morning and thank you for the invitation to give testimony at today's hearing.

My name is Diana Liverman. I am a professor at the University of Arizona, where we are proud to host federally funded centers for the climate assessment for the southwest with NOAA, and the Department of the Interior Regional Climate Science Center. We also have a Center for Climate Adaptation, Science, and Solutions, that made many contributions to the U.S. National Climate Assessments.

I studied climate change and its impacts for 40 years. I wrote my Ph.D. on climate change and food security at UCLA and the National Center for Atmospheric Research in Colorado. I worked for the University of Wisconsin, Penn State, and Oxford University. And although I have been a U.S. citizen for 30 years, I have retained my British accent because students in my classes apparently are finding it more interesting and more convincing.

You invited me to speak about the recent special report of IPCC on global warming of 1.5 Celsius, requested by countries as part of the decision to adopt the Paris Agreement. I was a lead author for chapter 5 of the main report, nominated by the U.S. Government, and I also contributed substantially to the summary for policymakers. We released the report written by 91 authors from 40 countries in October 2018. We assessed more than 6,000 scientific studies, and received over 40,000 comments from governments, scientists and other expert reviewers that helped us improve the report.

What did the report conclude? My written testimony provides much more detail, but let me summarize some of the key messages: First, the Earth is already warmed on average by 1 degree Celsius, that is about 1.8 Fahrenheit, even more over land and towards the poles. And we are already seeing impacts and losses from the warming. In the U.S., the warming has been greatest in Alaska, but also in the southwest where I live, where the annual average temperature has increased since 1901, with parts in southern California and Arizona warming by more than 4 degrees Fahrenheit.

Warming has led to lower flows on the Colorado, increased the risk of wildfires across the west. It is altering our ecosystems, and stressing the electrical grid and agriculture. It has already increased the risk of species extinction, shifted agricultural zones, and affected human health. Tucson, where I live, now has 25 more days above 100 degrees Fahrenheit than it did in 1970. This heat has especially affected our most vulnerable citizens, the poor, the elderly, children, as well as tribal members, people of color and folks who work outdoors. Many people can't afford the increased air conditioning and water costs.

Secondly, every bit of warming matters. The IPCC found significant differences in climate and impacts between 1.5 Celsius and 2 Celsius, that is 2.7 and 3.6 Fahrenheit. For example, sea level rise by 2100 would be 6 inches more at 2 degrees with added risks if ice sheets become more unstable. Even a few inches of sea level rise increases the risks of coastal flooding, salt water intrusion, and damage to infrastructure.

The loss of habitat for many insects, plants and animals doubles, even with that extra half degree. Fire risk is higher, and fisheries are more disturbed. At 1.5 degrees Celsius, we lose about 70 percent of tropical corals, at 2 degrees they disappear. Poverty increases by several hundred million, and in many regions, water stress and heat wave deaths double, agricultural production declines, and diseases can increase.

My third point is that we can reduce losses now, and at 1.5 degrees Celsius, if we focus on adapting to ongoing warming. Limiting warming to 1.5 Celsius makes that adaptation easier and less costly. U.S. communities and businesses are already making costly adaptations to cope with observed warming.

The University of Arizona is working with stakeholders across the southwest, water managers, conservation scientists, farmers and communities to develop and implement adaptation solutions.

Fourth, limiting warming to 1.5 is possible. The world is not on track if we want to limit warming to 1.5. The IPCC concluded that the voluntary commitments pledged so far under the Paris Agreement still take us to 3 degrees. But there is a chance to stay under 1.5, if we cut emissions in half by 2030, and reach net zero emissions by 2050.

The U.S. can make important contributions to the rapid and far-reaching transitions in energy, land, urban infrastructure, and industrial systems that could help limit warming to 1.5. Delaying emission reductions could be very costly. If we choose to delay, we may lose the chance to stay under 1.5 degrees Celsius, or we will have to make deeper and more expensive cuts in emissions, rely on untested technologies, experience greater losses, or adapt to higher temperatures. Halving emissions by 2030, starting now, sets us on the path to success. The world will not end if we don't make these emission cuts by 2030, but that world will be much harder for us to live in. Thank you.

[The statement of Dr. Liverman follows:]

Written Testimony of Diana M Liverman
Regents Professor of Geography and Development
University of Arizona

Hearing on "Solving the Climate Crisis: Drawing Down Carbon and Building Up the American Economy"
United States House Select Committee on the Climate Crisis

April 30th 2019

Good morning. Chairwoman Castor, Ranking Member Graves, and members of the committee, thank you for the invitation to testify at today's hearing.

My name is Diana Liverman and I am a Regents Professor of Geography and Development at the University of Arizona. I have studied climate for 4 decades beginning with my graduate work on climate change and food security at UCLA and the National Center for Atmospheric Research in Colorado, and in faculty positions at the University of Wisconsin, Penn State, Oxford University, and the University of Arizona. I am an expert on the impacts of climate on society and on climate adaptation.

Although I have been a US citizen for decades, I have retained my British accent because my students tell me it helps them pay more attention in lectures.

When 40 years ago, as a student, I first heard that human activities were increasing greenhouse gases, CO_2 was around 335ppm, 25% above a baseline prior to the Industrial Revolution[1]. I learned that if we continued to emit CO_2 and doubled concentrations, global temperatures could warm more than 3°C.

My graduate work at UCLA showed that this could have serious impacts on food security and on crop yields in the US and across the world.

Since then, the rise in CO_2 has continued. Now, 4 decades later, the increase in greenhouse gas concentrations, has brought us to almost 410ppm, a 50% increase over the baseline. We have already seen the onset of warming of more than 1°C global average (1.8°F) and we are headed for more than 3°C (5.4°F) if trends continue.

In my hometown of Tucson, I have observed how warming is increasing extreme heat and fire risks, bringing more intense storms, threatening water supplies from the Colorado River and altering ecosystems. Climate change is affecting our most vulnerable or historically disadvantaged citizens – the poor, the elderly, and children, tribal members, farm and construction workers who labor outside – who cannot escape the heat or afford the increased air conditioning and water costs.

I welcome the interest of this committee in what can be done to reduce the risks of dangerous climate changes.

[1] *Climate.gov*

The IPCC SR1.5°C

I have been asked to speak to the committee about the recent special report of the Intergovernmental Panel on Climate Change (IPCC) on Global Warming of 1.5°C[2]. I was a lead author, nominated by the US government, of Chapter 5 of the main report and I also contributed substantially to the Summary for Policy Makers. I have also contributed to the US National Climate Assessment (NCA). I include the IPCC Summary for Policy Makers and the Southwest chapter of the US National Climate Assessment as appendices to my testimony.

In its decision on the adoption of the Paris Agreement in 2015, the Conference of Parties (COP) to the United Nations Framework Convention on Climate Change invited the IPCC to provide a special report on the impacts of global warming of 1.5°C. The IPCC accepted this invitation and released this special report in October 2018. 1.5C converts to 2.7°F. I will use 1.5°C in referring to the report.

The report is the product of a team of 91 authors and editors from 40 countries. We assessed more than 6,000 scientific studies and received over 40,000 comments from governments, scientists, and expert reviewers that helped us improve the report.

The IPCC special report responds to the government approved outline that asks several key questions:

> *What are the warming trends and impacts and how close are we to 1.5°C already?*
> *Is there a significant difference between a global average warming of 1.5°C and one of 2°C?*
> *What would it take in terms of emission cuts to limit warming to 1.5°C?*
> *What are the implications for sustainable development?*

The full report is more than 250 pages and has a 31-page Summary for Policy Makers, which was approved by the 195-member governments of the IPCC Panel as an accurate summary of the underlying scientific report, which is included as part of my written testimony. Below, I summarize some of the key findings of the report that may be of interest to this committee.

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[2] IPCC, 2018: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, Maycock, M. Tignor, and T. Waterfield (eds.)]. *World Meteorological Organization, Geneva, Switzerland, 32 pp.*

IPCC, 2018. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

The earth has already warmed on average by 1°C (1.8°F) and we are already seeing impacts and losses from this warming

Warming is greater over land regions, especially the Arctic. In the US warming has been greatest in Alaska, New Mexico, and Arizona (Figure 1). In the Southwest US and California, the annual average temperature has increased by 1.6°F between 1901 and 2016, with parts of southern California and Arizona warming more than 4°F[3]. In the Colorado River Basin, drought, high temperatures due mainly to climate change have contributed to lower runoff and to 17%–50% of the record-setting streamflow reductions between 2000 and 2014 (Figure 2).

These changes are detectable in how we feel out of doors, how much water we use to irrigate farms and gardens and in our air conditioning bills. Tucson now has almost 17 more days above 105°F and 25 days above 100°F than in 1970. This warming has increased the risk of drought and wild fires (Figure 3) and is especially tough on those who work outdoors, occupy poor quality housing, or who find it hard to pay their utility bills. There is stress on the electrical grid from increased demand, from wildfire risk, and from operating inefficiencies at high temperature.

The IPCC and the 4th US National Climate Assessment (NCA4) provide comprehensive assessments of the scientific literature. The Special Report on warming of 1.5°C and the National Climate Assessment concluded that scientific studies show that warming so far has increased the risks of species extinction, shifted agricultural zones and risks, affected human health, and increased the risks and intensity of some natural disasters.

Figure 1: Warming since 1901 in SWUSA (source Fig 25.1)

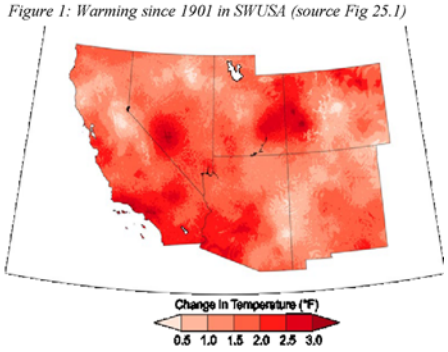
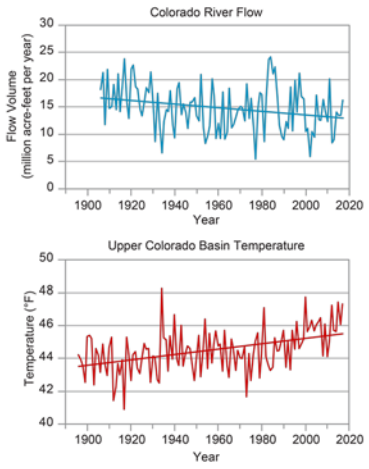


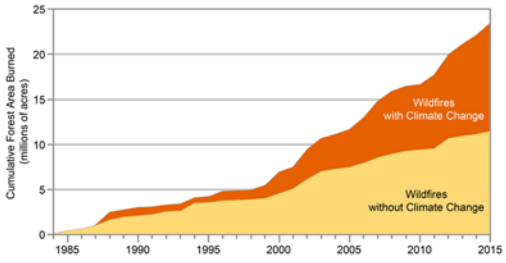
Figure 2: Changes in flow of Colorado and temperature change since 1900 (Source NATOINAL CLIMATE ASSESSMENT4, Fig 25.3)



[3] Gonzalez, P., G.M. Garfin, D.D. Breshears, K.M. Brooks, H.E. Brown, E.H. Elias, A. Gunasekara, N. Huntly, J.K. Maldonado, N.J. Mantua, H.G. Margolis, S. McAfee, B.R. Middleton, and B.H. Udall, 2018: Southwest. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment (**NCA4**), Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 1101–1184. doi: 10.7930/NCA4.2018.CH25

US communities and businesses are already making costly adaptations to cope with observed warming, including relocating away from coasts, reinforcing infrastructure, and increasing overall resilience to climatic extremes[4]. Internationally, warming is undermining decades of investment in economic development, and these international impacts are disrupting supply chains for US business and are of concern to national security.

Figure 3: Area burned by wildfires across Western US 1984-2015 (Source: Fig 25.4 NCA4)

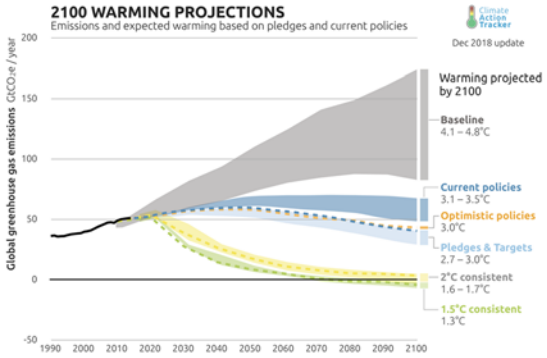


We are not on track if we want to limit warming to 1.5°C

Global warming is likely to reach 1.5°C between 2030 and 2052 if the current warming rate continues. Because greenhouse gases remain in the atmosphere for decades or more, and oceans store heat for many decades, additional warming is guaranteed. But as the IPCC report states, if we stopped emissions today, we could limit climate change to under 1.5°C.

The Paris Agreement provides an international framework for collective commitments to reduce and monitor emissions and adapt to climate change. The IPCC concluded that the voluntary commitments pledged only limit warming to 3°C (5.4°F), much warmer than 1.5°C (Figure 4). The Paris agreement does assume commitments to reductions will increase and provides the framework for taking stock and ratcheting up commitments over time.

*Figure 4: Projected emissions and temperatures based on current policies and pledges (Source: Climate Action Tracker, Dec 2018)_*



[4] Lempert, R., J. Arnold, R. Pulwarty, K. Gordon, K. Greig, C. Hawkins Hoffman, D. Sands, and C. Werrell, 2018: Reducing Risks Through Adaptation Actions. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 1309–1345. doi: 10.7930/NCA4.2018.CH28

Every bit of warming matters

The IPCC was asked whether there was a difference between 1.5°C and 2°C warming (2.7°F and 3.6°F). We concluded that every bit of warming matters. There are higher risks for natural and human systems at 1.5°C compared to the present, and those risks increase if warming rises above 1.5°C to 2°C. A half a degree extra global average warming from 1.5°C to 2°C would mean greater increases in temperature for most land and ocean regions, increases in heat extremes, and increases in the risk of droughts in some regions.

Sea level rise by 2100 would be between 10 and 30 inches at 1.5°C and 4-6 inches more at 2°C with added risk if ice sheets become unstable. Even a few inches of sea level rise increase the risks of coastal flooding, saltwater intrusion, and damage to infrastructure. The Arctic would be ice free in summer once per century at 1.5°C compared to once per decade at 2°C.

The impacts on ecosystems and natural resources are projected to be higher at 2°C than 1.5°C. The IPCC cites studies suggesting that the loss of habitat for many insects, plants, and animals doubles from 1.5°C to 2°C. Fire risk is lower at 1.5°C and fisheries are less disturbed. At 1.5°C we lose about 70% of corals, at 2°C they disappear.

2°C compared to 1.5°C increases the people who are poor and vulnerable by several hundred million, increases the risks of heat related deaths and disease, and increases the incidence and geographic shifts in malaria and dengue in some regions. Water stress is higher by up to 50% in many regions at 2°C. In many regions, including the southern parts of the US, warming reduces crop yields and stresses livestock, with greater stress on agriculture at 1.5°C than 2°C. Warming shifts some crop zones to higher latitudes and lengthens the growing season but these increases in crop production do not balance the agricultural losses at either 1.5°C or 2°C.

Adaptation is an important option – it can reduce losses now and at 1.5°C, but may reach some limits at higher temperatures

We are already seeing adaptation to a warmer climate across the world, and the US, in response to the warming climate. In the Southwest of the US, the University of Arizona is working with water managers, conservation scientists, farmers and communities to develop and implement solutions that reduce the risks of climate change. Both the IPCC report and the 4th US National Climate Assessment identify a broad range of ongoing and feasible adaptations that include reinforcing infrastructure such as coastal protection and energy systems, increasing water use efficiency in cities and farms, designing cities and buildings for warmer temperatures, improving disaster warning and insurance, and protecting natural ecosystems.

Limiting warming to 1.5°C makes adaptation easier and less costly than if we warm to 2°C or higher. At 2°C risks from rising seas, drought, and heatwaves are higher and would require more investment, innovation, and even relocation to avoid losses than at warming of 1.5°C.

If temperatures rise higher than 2°C we can encounter limits to adaptation when, for example, heat stress means that crops, livestock and wildlife can no longer survive in a particular location or when sea level rise and severe storms mean that facilities and communities must relocate away from coast. The loss when families lose their farms, a species becomes extinct, or a community abandons their land, is immeasurable and irreparable.

It is possible to effectively link reducing emissions to adapting to warming. There are response options, such as building design for lower emissions and higher temperatures, or farming for carbon sequestration and water conservation, that are wins for both adaptation and emission reductions. Research suggests that the synergies - the possibilities for win-win solutions - are greater when adaptation and mitigation are considered together.

Limiting warming to 1.5°C is possible

The IPCC report finds that it is possible to limit warming to 1.5°C if we make steep cuts in emissions and make a transition to a lower carbon energy system. For a good chance to stay under 1.5°C, emissions would need to be cut in half by 2030 and be net zero by 2050 (Figure 5).

The IPCC report suggests that these emission cuts can be achieved through an ambitious and exciting portfolio that increases energy efficiency and investment in renewables, reduces dependence on fossil fuels, supports forestry and land uses that sequester carbon, and develops bioenergy and carbon sequestration and storage. We looked at a range of possible trajectories for reducing warming with more or less immediate, or steep, declines in emissions and different levels of reliance on technologies to remove carbon dioxide from the atmosphere. These technologies include bioenergy and carbon capture and storage (BECCS/CCS) which, the IPCC, concludes are not yet viable for rapid deployment.

Figure 5: Illustrative pathway P2 that limits global warming to 1.5C with no or limited overshoot. Percent change is relative to 2010 (based on Fig SPM3b, IPCC SR1.5, 2018)

Action	2030	2050
Emissions	-47%	-95%
Energy Demand	-5%	2%
Energy from Coal	-61%	-77%
Energy from Oil	-13%	-50%
Energy from Gas	-20%	-53%
Energy from Nuclear	+83%	+98%
Energy from renewables (wind, solar, hydro, geothermal)	+470%	+1327%
Forests, CCS+Bioenergy	+348 GT	+151 GT

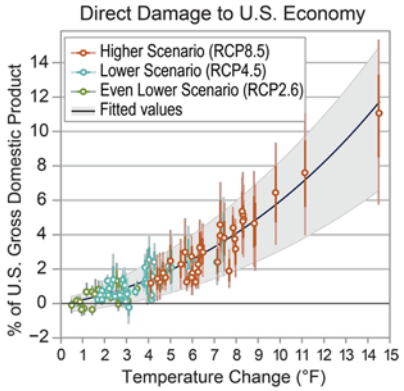
All scenarios include a decline in other greenhouse gas emissions, including methane, black carbon and nitrous oxide emissions. The pathways that provide the best chance of limiting global warming to 1.5°C are those that cut CO_2 emissions by 41% to 58% between 2010 and 2030. The amount of CO_2 we need to reduce depends on how much we reduce other greenhouse gases, such as methane and nitrous oxides, and how much we improve our carbon capture, through bioenergy or carbon capture and storage. Reducing our emissions dramatically by 2030 is a necessary step in order to reach the net zero CO_2 emissions needed by 2050 to meet the 1.5°C target. Net zero emissions are when remaining CO_2 emissions are balanced by removing CO_2 from the air with vegetation uptake or carbon capture.

The IPCC report evaluated the feasibility and impacts of a full range of response options to reach the 1.5°C target and the tradeoffs that occur with each scenario. For example, the expansion of bioenergy and forests would reduce emissions, but it would also reduce land available for crops and pasture.

To reach these reductions in CO_2, rapid and far-reaching transitions in energy, land, urban and infrastructure, and industrial systems will be needed. Many of these changes are already underway. These transformations can be achieved through a range of actions and policies, such as a carbon price combined with a shift and increase in investment. Current global energy investment is estimated at $2.3 trillion, about 1/3 in renewables and energy efficiency, and would need to increase to about $3 trillion, with 2/3 in renewables and efficiency, to limit warming to 1.5°C. These extra costs are balanced by the significant reduction in impacts and losses if we make the investments.

The IPCC economic impact projections show that limiting warming to 1.5°C rather than 2°C would avoid $15-38 trillion in damages by the end of the century (IPCC SR1.5 Section 3.5.2.4 and Box 6) with more serious impacts in developing countries. The report cites papers finding that economic damages in the US will be 0.2%-0.6% higher at 2° than 1.5°C. According to the 4th National Climate Assessment, the US could lose 2.3% of GDP per degree of warming (Figure 6).

Figure 6: Projections of direct damage to the US economy as a function of global average temperature change from multiple models. The RCP2.6 scenario is closest to a pathway limiting warming to 1.5°C. The dots are the median damages and the whiskers show the range of results (NCA4 2018, Figure 29.3).



The US is already showing momentum through historic transformations in the power sector with growth in renewables, electric vehicles, and efficiency, and our potential for technology innovation.

There are additional opportunities for the US to capture emissions in well managed forest and agricultural systems which store carbon. The 4th National Climate Assessment highlights the role of increasing forest area and increasing soil carbon storage in reducing greenhouse gas emissions (Chapter 5) supported by the Second State of the Carbon Cycle in North America report[5].

The IPCC report focuses on the global scale of emission cuts needed to limit warming to 1.5°C and the options for changes across different sectors, such as energy, land and technology, but it does not specify the country by country reductions needed. For example, one scenario suggests a 47% cut in CO_2 emissions is needed between 2010 and 2030 (20 years). Since we are in 2019 that translates into at least halving emissions in the next 11 years. But IPCC does not suggest who should make those cuts in emissions. Various options are examined in the research literature including equal percent, absolute allocations according to current shares of emissions, per capita emissions, historical emissions, consumption-based emissions, and capabilities. Many of these options place an even steeper emission cut on the US.

Delaying emission reductions could be costly

To summarize the key messages from the IPCC Special Report on 1.5°C: The world has already warmed by an average of 1°C with significant impacts and every bit of extra warming will bring greater losses. To have a chance of limiting warming to 1.5°C, we need to halve emissions by 2030 in order to reach net zero emissions by 2050. And to respond to the negative impacts of warming already underway and anticipated, we need to devote considerable thought and resources to adaptation.

The IPCC report recommends that the best change of limiting climate change to 1.5°C requires dramatic action now. If we choose to delay the emission reductions we may lose the chance to stay under 1.5°C, or will have to make deeper and more expensive cuts in emissions, rely on untested technologies, experience greater losses, or adapt to higher temperatures.

Halving emissions by 2030, starting now, sets us on the path to success. While the world itself will not end if we do not make these emission cuts by 2030, that world will be much harder for us to live in.

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[5] USGCRP, 2018: Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, P. Romero Lankao, and Z. Zhu (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 878 pp., https://doi.org/10.7930/SOCCR2.2018.

Ms. CASTOR. Thank you very much.

Mr. Guith, you are now recognized to give a 5-minute presentation on your testimony.

STATEMENT OF CHRISTOPHER GUITH

Mr. GUITH. Thank you.

Good Morning, Chairwoman Castor, Ranking Member Graves and members of the committee. The U.S. Chamber appreciates the opportunity to testify today on the important role of technology and innovation in addressing climate change. Global climate change is one of the most complex and far-reaching issues facing governments in the business community. The Chamber recognizes the climate is changing, humans are contributing to these changes, and these changes pose risks. The question for business and policymakers is how best to manage these risks, capture opportunities, and maintain our global economic leadership. But inaction is not an option. The Chamber believes there is much common ground on which all sides of this discussion could come together to craft a practical, flexible, predictable, and durable approach to climate change that acknowledges the cost of action and inaction and the competitiveness of the U.S. economy. Because the business community will be integral to developing and providing cost effective solutions and building resilient infrastructure, it will continue to be at the table.

The Chamber believes that technology and innovation are integral to managing climate risks and reducing emissions across the U.S. as well as the globe. Instead of regulating our way to lower emissions, a realistic, effective and lasting climate policy should focus on innovating our way to technological solutions. Breakthroughs and commercially viable technology are necessary to enable significant cuts in emissions without harming economic growth or competitiveness of energy intensive and trade exposed industries.

Existing technologies have started us on the path, but they are not capable of significantly reducing greenhouse gas emissions on a global scale at an acceptable cost. New, and in some cases, revolutionary technologies, will have to be developed and adopted commercially, along with the infrastructure to support them.

Some of these technologies may never reach viability, but that does not mean we shirk the duty of trying to develop them. A technology neutral, solutions-focused climate policy is best positioned to stand the test of time and deliver cost effective, achievable, and meaningful greenhouse gas reductions.

In the meantime, we should continue to develop our domestic energy resources which provide our businesses a critical operating advantage in today's intensely competitive global economy. We should work to preserve that advantage, recognizing that disproportionate international commitments could cause American industrial capacity to move to other countries through carbon leakage.

A policy that promotes continued economic growth and environmental progress through sustained focus on technology development where what we at the Chamber call the cleaner, stronger approach, is much more popular with the voting public compared to an approach centered on expanding government regulation. Last

month, we commissioned a national poll that found 79 percent of voters agreed that the best way to address climate change is through investment, and innovation, and technology, which was a 24-point advantage over increased government regulation. Additionally, voters prefer a cleaner, stronger focus to a Green New Deal approach by more than three to one.

And finally, more than 64 percent of voters would spend no more than $10 a month to address climate change. These results underpin the Chamber's efforts to promote bipartisan Federal policies and investments that spur technologies that can reduce environmental impact and compete on price and reliability.

It will largely be up to the business community to develop, finance, build, and operate the solutions needed to power economic growth worldwide, while mitigating greenhouse gas emissions. Thousands of businesses already have made emissions commitments and are taking action to reduce emissions in their own operations and along their value chains. To draw attention to what the energy industry is doing, last summer, we launched a new initiative to highlight that the energy industry has been one of, if not the most innovative industries, over the last decade. Our program, called Energy Innovates, highlights specific innovative projects and technologies, as well as the forward thinkers, engineers, and manufacturers responsible for further development.

This summer, the Chamber is hosting an energy innovation summit to help policymakers here in Washington better conceptualize the exciting development happening across the country.

Climate change is a global challenge, and U.S. technological leadership will be vital in addressing developing country emission trends. Virtually, all future greenhouse gas emission growth is expected to come from developing countries. Much of these increases are related to a sharp increase in coal-fired electricity generation expected to be built there. As such, technology and innovation will be even more important in addressing developing country emission trends.

Make no mistake, the developing world's desire for greater energy access is not an argument for inaction. As we stated, inaction is not an option. However, failure to recognize the global nature of climate change leads to a solution set that is ineffective. Advanced technologies that compete with traditional fuels on cost, reliability and scalability can reconcile the sometimes competing quest for energy access and desire for emissions reductions.

Technology supported by sound policy will be essential to tackling the challenges and capitalizing on the opportunities presented by climate change. The Chamber will continue to support an accelerated program to improve performance, lower the cost, and increase scalability of energy technologies. There are a number of near-term legislative actions on which there is broad consensus, such as technology and innovation that the Chamber supports, and on which Congress could act.

I listed several in my written testimony, and we encourage all of you to cosponsor these bills. America's business community is ready, willing and able to continue to provide the solutions to reduce emissions while growing the economy. With the sensible policy environment that plays to America's strengths and business

leadership, we can continue making our economy cleaner and stronger. An approach focusing on solutions offers a practical path forward that makes good sense and good business sense.

Thank you, Madam Chairman.

Ms. CASTOR. Thank you very much.

[The statement of Mr. Guith follows:]

Statement of the U.S. Chamber of Commerce

ON: "Solving the Climate Crisis: Drawing Down Carbon and Building Up the American Economy"

TO: U.S. House of Representatives
Select Committee on the Climate Crisis

DATE: April 30, 2019

My name is Christopher Guith and I am the Acting President of the Global Energy Institute, an affiliate of the U.S. Chamber of Commerce ("Chamber"). The mission of the Global Energy Institute is to unify policymakers, regulators, business leaders, and the American public behind a common sense energy strategy to help keep America secure, prosperous, and clean. The Chamber appreciates the opportunity to testify today on the important role of technology and innovation in addressing climate change.

Introduction

The Chamber's mission is to take on the challenges facing the American business community at home and around the world. Global climate change is one of those challenges.

Global climate change is one of the most complex and far-reaching issues facing governments and the businesses community. The Chamber recognizes that the climate is changing, humans are contributing to these changes, and these changes pose risks. The question for businesses and policymakers is how to best manage these risks, capture opportunities, and maintain our global economic leadership. Inaction is not an option.

The Chamber believes there is much common ground on which all sides of this discussion could come together to craft a practical, flexible, predictable, and durable approach to climate change that acknowledges the costs of action and inaction and the competitiveness of the U.S. economy.

Climate change is one of the most complex issues facing governments, businesses, and our communities. Addressing it, as well as not addressing it, will affect economies, companies, and communities in significant and often unpredictable ways, affecting investments, operations, planning, supply and value chains, and trade, among other issues. Accordingly, climate change should be addressed as part of an agenda that increases economic prosperity, reduces greenhouse gas (GHG) emissions, mitigates associated risks, and enhances energy security. Because the business community will be integral to developing and providing cost-effective solutions and building resilient infrastructure, it will be at the table.

Climate Change is a Technology Challenge

At its most fundamental level, reducing carbon dioxide emissions from energy is a technology challenge that, as a 2002 article in *Science* famously noted, "cannot be simply regulated away."[1]

The Chamber believes that technology and innovation, supported by sound and durable policies, offer the best solution for managing climate risks and reducing emissions across the United States and the globe. Instead of regulating our way to lower emissions, a realistic, effective, and lasting climate policy should focus on innovating our way to technological solutions that can thrive in commercial markets.

[1] Hoffert, M. *et al.* 2002. Advanced technology paths to global climate stability: energy for a greenhouse planet. *Science* 298: 981.

Breakthroughs in commercially-viable technologies are necessary to enable significant cuts in GHG emissions without harming economic growth or the competitiveness of energy-intensive trade-exposed industries. Indeed, the development of technology and its commercial adoption are among the most important factors determining how quickly and at what cost greenhouse gas emissions can be reduced. Existing technologies have started us on this path, but they are not capable of significantly reducing greenhouse gas emissions on a global scale and at an acceptable cost. New, and in some cases revolutionary, energy technologies will have to be developed and adopted commercially along with the infrastructure to support them. There is a great deal of uncertainty about how fast, or even if, all of these technologies will progress.

The U.S. must maintain a leadership role in developing and commercializing technologies, such as advanced nuclear, energy efficient systems and building materials, and large-scale renewables, energy storage and batteries, high-efficiency low-emission power plants, and carbon capture and storage and utilization by supporting an aggressive, broad-based public- and private-sector technology portfolio. It is also important to support a vibrant scientific enterprise more broadly. Advances in fields as varied as materials research, nanotechnology, supercomputing, and biotechnology, to name a few, may hold the keys to breakthroughs in many emerging energy technologies.

Energy efficiency remains a crucial component of the approach to energy and climate change. Energy efficiency generally has been the fastest, least expensive way to improving the energy supply picture and reduce GHG emissions. It, too, must play a central role.

A technology-neutral solutions-focused climate change policy is best positioned to stand the test of time and deliver cost-effective, achievable, and meaningful greenhouse gas emissions reductions. When alternate technologies are able to compete on price, reliability, and scalability, the range of politically and economically acceptable policy options to address climate change will broaden accordingly.

In the meantime, we should continue to develop our domestic energy resources, the world's largest. America's abundance of affordable, reliable energy provides businesses a critical operating advantage in today's intensely competitive global economy. International Energy Agency data show a huge comparative energy advantage in natural gas and electricity for U.S. industry compared to its Organization for Economic Co-operation and Development (OECD) competitors, with prices for these energy sources in the United States often two to four times less.[2] We should work to preserve that advantage, recognizing that disproportionate international commitments could cause American industrial capacity to move to other countries through carbon leakage.

Strong Public Support for Technology and Innovation

An energy policy that promotes continued economic growth and environmental progress through sustained focus on technology development—what we call the "cleaner, stronger" approach—is

[2] International Energy Agency. 2018. *Key World Energy Statistics.* Available at: https://webstore.iea.org/key-world-energy-statistics-2018.

much more popular with the voting public compared to an approach centered on expanded government regulation.

GEI commissioned a telephone survey[3] of 1,000 likely 2020 voters across the United States conducted by FTI Consulting from March 7-12, 2019 found:

- 73% of voters support a "cleaner, stronger" energy agenda that uses more American energy and continues environmental progress;
- "Cleaner, Stronger" is favored over a Green New Deal approach by more than 3:1;
- 89% of Americans support using American's energy resources responsibly, including domestic natural gas, oil, nuclear, coal and renewable resources;
- 79% of voters agree that the best way to address climate change is through investments into innovation and technology;
- Utilizing innovation and technology has a 24-point advantage over increased government regulation as an approach to address climate change; and.
- 79% of likely voters support streamlining or expediting the permitting process to improve, modernize or construct critical energy infrastructure like renewables, pipelines, power plants, transmission lines and export facilities.

Our new survey demonstrates that voters are concerned about energy, the environment, and climate change, but they are also concerned about the costs and practicality of an approach to those issues driven primarily by government regulation. Given the current state of technology, a regulatory approach involves significant price increases.

These results underpin the Chamber's efforts to promote federal policies and investments that spur research and development of energy technologies that can reduce environmental impacts and compete on price and reliability.

Business is Taking Action

It will be largely up to the business community to develop, finance, build, and operate the solutions needed to power economic growth worldwide, mitigate greenhouse gas emissions, and build resilient, lower-carbon infrastructure. Thousands of businesses already have made emissions pledges and are taking action to reduce emissions in their own operations and along their value chains by investing in technology solutions and enhancing their efficiency. The Chamber is providing a platform for these companies to share their experiences and learn about technology developments, and operational innovations.

Energy Innovates: To draw attention what the energy industry is doing, last year GEI launched a new initiative to highlight the technologies and people in the energy industry that are improving our modern way of life. "*EnergyInnovates*" is a multi-platform initiative that showcases innovators, projects, and technologies that have shaped and will shape America's energy landscape. *EnergyInnovates* highlights specific innovative projects and technologies, as

[3] Poll results are available at: https://www.globalenergyinstitute.org/american-energy-cleaner-stronger.

well as the forward thinkers, engineers, and manufacturers responsible for their development. Some of the initiatives we are featuring include:

- San Diego Gas & Electric Company (a Sempra Energy utility) has built a lithium ion battery storage facility in Escondido, California, the largest in North America and a key component of the smart grid technology that will maximize the potential and availability of intermittent renewable energy resources.

- NuScale's small modular nuclear reactor with a simplified design, making it safe, scalable, cost efficient, and able to perform a wide range of applications, including desalinating, supporting renewables, and providing highly reliable power.

- NET Power's innovative power plant leverages technology designed to capture carbon dioxide emissions at no extra cost, before compressing and recirculating the gas into the system. Called the Allam Cycle, the system will allow efficient, zero-emission energy production using fossil fuels.

- Alabama Power's Smart Neighborhood™ features a collection of 62 homes that feature high-performance, efficient systems, cutting edge interconnectivity, and a dedicated micro-grid featuring solar, battery storage, and natural gas power supplies. The project is a public-private partnership between Southern Company, Signature Homes, the U.S. Department of Energy's Oak Ridge National Laboratory, and others.

Our companies and entrepreneurs will continue to lead by bringing innovation, technology, and ingenuity to this challenge, just as they have done with other environmental challenges.

Energy Access and Technology

Climate change is a global challenge, and U.S. technological leadership will be no less important in addressing developing country emission trends.

Virtually all future GHG emissions growth is expected to come from developing countries, where economic development and eradication of energy poverty are pressing issues. The International Energy Agency's most recent forecast indicates that while energy-related carbon dioxide emissions from OECD countries are expected to drop from about 1 to 2.6 billion metric tons (-8% to -23%) between 2017 and 2040, emissions from non-OECD countries are expected to increase 5.3 to 10.0 billion metric tons (27% to 50%), offsetting developed country reductions by a large margin. Much of these increases are related to a sharp increase in coal-fired electricity generating capacity expected to be built in developing countries.[4] Technology and innovation will be no less important in addressing developing country emission trends.

Make no mistake, this is not an argument for inaction, as we have stated, inaction is not an option. However, failure to recognize the global nature of climate change leads to a solution set that is ineffective.

[4] International Energy Agency. *World Energy Outlook 2018*. Available at: https://www.iea.org/weo2018/.

Modern life is inconceivable without adequate supplies of energy, and there exists a very strong and unsurprising correlation between peoples' living standards and energy use. Nearly a billion people worldwide still lack access to modern energy services; the situation in Africa is especially acute. Between the energy haves and the have-nots, there also are too many energy "have-littles," that is, people with access only to small and usually unreliable supplies of energy. Access to energy has to be consequential if it is to raise living standards significantly.

Data from the World Bank[5] indicate that—even more important than GDP or energy use per capita—access to electricity is the single best indicator for how well a country performs in key development measures such as infant and maternal mortality, life expectancy, vaccinations (many of which require refrigeration), girls in school, undernourishment, and other measures of health and welfare.

We must recognize and embrace the aspirations of people everywhere for economic growth, access to abundant and affordable energy, and improved quality of life. U.S. leadership can help achieve these goals.

With the suite of technologies available today, energy policies that strive to provide rapid and universal access to affordable and modern energy services for the poor are in tension with climate change policies that may increase energy costs and limit access to reliable energy services. Advanced technologies that compete with traditional fuels on cost, reliability, and scalability can reconcile these two competing visions. Given the expected growth in coal-fired generation, development of carbon capture and storage and/or use technologies will be particularly important. It is also important that we encourage the use of the most efficient and advanced technologies for fossil fuel use currently available, such a High-Efficiency, Low-Emissions—or HELE—coal plants, which can make a tremendous difference.

Demand for advanced technologies, especially in emerging markets, will offer opportunities for growing exports of American technologies, products, and services. Technology cooperation, public-private partnerships, innovative financing, and capacity building are all necessary for facilitating commerce in climate solutions stamped "Made in the USA."

Conclusion

Technology, supported by sound policy, will be the key to tackling the challenges and capitalizing on the opportunities presented by climate change. The Chamber will continue to support an accelerated program to improve performance, lower the cost, and increase the scalability of alternate energy and technologies.

There are a number of near-term actions on which there is sufficient consensus—such as technology and innovation—that the Chamber supports and on which Congress could act. Specifically, the Chamber encourages you and your Senate colleagues to take up the following priorities:

[5] World Bank Development Indicators are available at: https://data.worldbank.org/indicator.

- Improving energy efficiency by enacting provisions of the bipartisan Energy Savings and Industrial Competitiveness Act;
- Supporting greater utilization of carbon sequestration by
    - Enacting the bipartisan Utilizing Significant Emissions with Innovative Technologies Act (USE IT Act),
    - Expanding the allowable uses of private activity bonds to include investments in carbon capture infrastructure, and
    - Facilitating the construction of interstate carbon dioxide pipelines through accelerated permitting;
- Modernizing U.S. transportation infrastructure to improve efficiency and resiliency and speed the adoption of new technologies, including by
    - Enacting a multi-year highway bill with increases in overall funding financing through an increase in the motor vehicle fuel tax, and
    - Maintaining the Advanced Technology Vehicles Manufacturing Loan Program;
- Modernizing U.S. energy infrastructure to facilitate the transportation of low and zero-emission energy, including by providing the Federal Energy Regulatory Commission greater authority to site electric transmission lines and natural gas pipelines;
- Supporting the continued use of emissions-free nuclear power by finally providing for the permanent storage of used nuclear materials at Yucca Mountain;
- Reducing short-lived climate pollutants such as hydrofluorocarbons by ratifying the Kigali Amendment; and
- Significantly increasing funding in federal research, including the Advanced Research Projects Agency – Energy (ARPA-E), by dedicating a specific amount of any increased spending provided through a budget cap adjustment deal to clean energy research.

America's business community is ready, willing, and able to provide the solutions to reduce emissions while growing the economy. Our companies and entrepreneurs will continue to lead by bringing innovation, technology, and ingenuity to this challenge, just as they have done with other environmental challenges. With a sensible policy environment that plays to America's strengths and business leadership, we can continue to make our economy cleaner and stronger by leveraging America's edge in energy, technology, and innovation going forward. An approach focusing on solutions offers a practical path forward that makes good sense—and good business sense.

Biography of
Christopher Guith
Acting President Global Energy Institute
U.S. Chamber of Commerce

Christopher Guith is acting president at the U.S. Chamber of Commerce's Global Energy Institute (GEI). He is responsible for developing the Institute's policies and initiatives as they apply to the legislative, executive, and regulatory branches of the federal and state governments. Specifically, Guith primarily focuses on the development of GEI's policies and messaging relating to oil and natural gas, generation, and nuclear energy. He led the Chamber's Shale Works for US campaign, which analyzed and promoted the widespread benefits of shale energy development in America.

Guith offers expertise on an array of energy and environmental issues. He educates policymakers, businesses, energy stakeholders, coalitions, and the public about the importance of a diversified energy portfolio and how it can ensure an efficient, reliable, prosperous, and secure energy future. He also leverages his broad energy expertise as a spokesperson with local, state, and national media.

Guith travels frequently to speak to stakeholder groups, raising awareness of the impact of policy decisions on America's energy future and encouraging groups to share their perspectives with policymakers. In addition, he consults with state and local chambers of commerce and business groups, advising them how to quantify the importance of safe, reliable American energy to their businesses, as well as how to amplify that message when communicating with energy decision makers.

Prior to joining the Chamber in 2008, Guith served as deputy assistant secretary for nuclear energy at the U.S. Department of Energy (DOE), where he developed the administration's nuclear energy policies and coordinated the department's interactions with Congress, stakeholders, and the media. He was also deputy assistant secretary for congressional affairs at DOE and a chief representative of the administration during the drafting and debate of the Energy Policy Act of 2005.

Earlier in his career, Guith served as Rep. Bob Barr's (R-GA) legislative director and Rep. Tim Murphy's (R-PA) counsel and policy adviser. He was also legislative counsel for the Environment, Technology & Regulatory Affairs at the U.S. Chamber of Commerce.

Guith is a graduate of Syracuse University-College of Law and the University of California-Santa Barbara.

Ms. CASTOR. Mr. Foster, you are new recognized for 5 minutes.

STATEMENT OF DAVID FOSTER

Mr. FOSTER. Thank you. Good morning, Chairwoman Castor, Ranking Member Graves, and Hal Harvey for turning the mic on. I am pleased to be here today on behalf of the Energy Futures Initiative to speak to the important issue of the energy and energy efficiency workforces. Twelve years ago, in 2007, I testified to the Select Committee on Energy Independence and Global Warming. At that time, I stated one of the most famous American industrialists of the 20th century, Henry J. Kaiser, once observed, quote, "Problems are just opportunities in work clothes." While 12 years later, I am pleased to report that millions of Americans have put on their work clothes and got about the business of solving climate change. Today, of the 6.7 million Americans who work in the energy and energy efficiency industries, over 3.5 million, more than 50 percent, are contributing to a lower emissions economy. 350,000 of them do this in the wind and solar energy industries; another 63,000 in nuclear power plants; 66,000 in hydro; 70,000 in low emissions, advanced natural gas generating plants; and thousands of others in geothermal, combined heat and power, battery storage, and many other technologies including several hundred at the first coal-fired power plant retrofitted with carbon capture technology at the Petra Nova generating station, just south of Houston, Texas.

If it is done right, with the interest of America's middle class and working families at heart, there will be a place at the table, a job, and a paycheck, for every American while we solve the climate crisis. But we do have to do it right. Most of the Americans whose jobs are reducing greenhouse gas emissions today are working with energy efficiency technologies. In fact, almost 2.35 million people work in energy efficiency in the United States, retrofitting our buildings, installing LED lighting systems, and manufacturing high efficiency HVAC systems and hundreds of other ENERGY STAR certified products.

In transportation, almost 254,000 Americans now work manufacturing hybrids, all electrics, and plug-in hybrids, while another 486,000 work in the motor vehicles component parts industry, specifically on those products that make our automotive fuel consumption more efficient. This is how we solve climate change, by doing the hard work every day and getting a paycheck from construction work, factory jobs, for mining critical minerals like copper, iron ore and palladium and designing, financing, and permitting the systems and products that create our low carbon economy.

So what are some of the effective job strategies for dealing with the disparities that are inevitable in the transition to a low carbon economy? First, we need to embrace an all-of-the-above flexible strategy towards climate solutions. There is no silver bullet that can guide our economy to a low carbon endpoint guaranteeing CO_2 reduction and a decent job for every American. But we can invest in a range of technologies and options that preserve flexibility and encourage participation in every form of energy and in every community during the next decade. From renewables and battery storage in California, to carbon capture and sequestration in Appalachia, to small modular reactors in Idaho.

Second, we need to accelerate our investments in energy efficiency with a special priority on those regions of the country negatively impacted by declining use of fossil fuels. The third strategy is to invest in energy infrastructure. The existing DOE loan program office, with $39 billion of existing loan authority, could be particularly helpful in jump-starting such an initiative.

Fourth, we need to focus on the manufacturing supply chains that our new energy technologies are creating. The ENERGY STAR brand promoted by the U.S. EPA is one of the strongest product marketing brands in the world, recognized as the gold standard for efficiency, using a new ENERGY STAR, Made in America procurement policy to support the manufacturer of best in class products would be one of best paths forward to a resurgence in American manufacturing. Carbon performance should be a universal procurement standard for government spending in the U.S., similar to what California recently did with its Buy Clean standard.

Finally, we need to address the workforce development crisis across all energy technologies, but particularly in energy efficiency. In 2017, energy efficiency construction employers have projected hiring at 10.6 percent for over 120,000 new jobs. But the reality of hiring difficulty got in the way, and they added only 21,000 jobs in 2018. This was a failure of our workforce development system with very real-world consequences. From the environmental perspective, millions of tons of CO_2 went into the atmosphere that could have been prevented. But from the human perspective, this represented over 100,000 families that could have entered the middle class with some of the best paying jobs in America.

I want to close by thanking the committee, again, for the opportunity to testify. With sound economic analysis, accurate jobs data and a collaborative approach, we can manage our path to a low-carbon economy by investing in new opportunities and new jobs first before we put old technologies on the shelf.

Thank you very much.

[The statement of Mr. Foster follows:]

Testimony to the House Select Committee on the Climate Crisis
David Foster, Distinguished Associate, Energy Futures Initiative
April 30, 2019

Good morning, Madame Chairwoman Castor and Ranking Member Graves. I'm pleased to be here today on behalf of the Energy Futures Initiative to speak to the important issue of the energy and energy efficiency workforce in our country during a time of considerable technological change and policy debate, both of which can have consequential effects on the lives of the men and women who work throughout our energy economy.

Twelve years ago, in 2007, I testified to the Select Committee on Energy Independence and Global Warming. At that time I reflected, "One of the most famous American industrialists of the 20th Century, Henry J. Kaiser, who built an innovative manufacturing enterprise that included aluminum, steel, and ship building and created the health care delivery system that still bears his name, once observed that "Problems are just opportunities in work clothes."

Twelve years later, I'm pleased to report that a lot of Americans have put on their work clothes and got about the business of solving climate change. Today, of the 6.7 million Americans who work in the energy and energy efficiency industries over 3.5 million, more than 50%, are contributing to a lower emissions economy. 350,000 of them do this in the wind and solar energy industries, another 63,000 thousand in nuclear power plants, 65,000 in hydro and 70,000 in low emissions advanced natural gas generating plants, and thousands of others in geothermal, combined heat and power, battery storage, and many other technologies, including several hundred at

the first coal-fired power plant retrofitted with carbon capture technology at the Petra Nova generating station, just south of Houston, TX. If it is done right, with the interests of America's middle class and working families, at heart, there will be a place at the table, a job and a pay check for every American while we solve the climate crisis. But we have to do it right.

Most of the Americans whose jobs are reducing greenhouse gas emissions today are working with energy efficiency technologies. In fact, almost 2.35 million people work in energy efficiency in the United States, retrofitting our buildings, installing LED lighting systems, and manufacturing high efficiency HVAC systems and hundreds of other EnergyStar certified products. They provide the design and engineering plans to restructure our built environment. They reduce the energy consumption in our energy intensive industries and in every way they are changing the way we interact with our environment.

In transportation, almost 254,000 Americans now work manufacturing and designing alternative fuels' vehicles including all electrics, hybrids, and plug in hybrids, while another 486,000 work in the motor vehicles' component parts industry, specifically on those products that make our automotive fuel consumption more efficient. This is how we solve climate change—by doing the hard work every day and getting a pay check from construction work, factory jobs, from mining the critical minerals like copper, iron ore, and bauxite, and designing, financing, and permitting the systems and products that create our low carbon economy.

For 31 years I worked with the United Steelworkers union, the last 16 as the Director of the 13-state District #11, based in Minnesota. In 2006 with the Steelworkers support, I was the founding executive Director of the Blue Green Alliance, a national organization that unified 10 labor unions and five environmental organizations with over 14 million members around a vision of a fair and just transition to a low carbon economy that would put money in working families' pockets and make America the leader in low carbon technologies. I also served for three years as Senior Advisor on energy, economic development, climate, and workforce issues to U.S. DOE Secretary Moniz from 2014–2017. I currently serve as a Distinguished Associate at the Energy Futures Initiative, an energy policy think tank, founded by the former Secretary and a consultant to the Roosevelt Project at the Massachusetts Institute of Technology. I also serve on the boards of two manufacturing companies, Kaiser Aluminum and Evraz, NA, a steel company.

While I was at the U.S. Department of Energy (DOE), I was responsible for overseeing the design and production of the U.S. Energy and Employment Report, an employer survey-driven study of how new energy technologies were affecting labor markets in the U.S. in five critical sectors—Fuels; Electric Power Generation; Transmission, Distribution and Storage; Energy Efficiency; and Motor Vehicles. We focused on these sectors because they were at the core of the system through which we create, distribute, and consume most of the energy in the American economy. After producing two editions of the U.S. Energy and Employment Report, I have continued this work at the Energy Futures Initiative in partnership with the National Association of State Energy Officials (NASEO). This partnership has produced two subsequent reports on the energy workforce, using the identical methodology we created at DOE, released in the spring of 2018 and most recently, the spring of 2019.

Energy jobs data is critical to measuring the economic success of any climate change mitigation program, pinpointing any adverse economic consequences, and crafting solutions for working people and communities that may be upended by changing energy technologies.

Here are some of the key findings of our reports:

Although the energy sector in the U.S. has steadily declined as a percentage of U.S. Gross Domestic Product (GDP) since the Oil Embargo of the 1970's, with one notable exception during the 2006–08 period, energy occupies a unique position in the American economy. It is the sector upon which every other sector is dependent.

Today's energy and energy efficiency sectors employ 6.7 million Americans, with 35% of those employees focused on energy efficiency, 19% engaged in transmission, distribution and storage of fuels and electricity, 17% producing fuels, another 13% producing electricity, and 15% working in gas stations.

For the last four years, the energy and energy efficiency sectors have out-produced the rest of the American economy, creating jobs at a more rapid rate than the economy as a whole. In 2018, the U.S. economy increased jobs by 1.8%, while the energy and energy efficiency sectors added jobs at 2.3%, creating 7% of all new jobs.

It is critical to understand that an economy whose energy sector is constantly becoming more productive, more efficient and more cost competitive not only creates jobs itself, but also stimulates job creation in every other sector of the economy including in manufacturing, construction, agriculture, health care, or IT services. En-

ergy is a critical cost component that links systems, enables innovation, and stokes global competitiveness. We need only look to neighboring economies where the cost of energy, inefficient energy systems, and unreliable delivery infrastructure disrupt and slow economic activity.

Our energy system starts with the production of fuels which today employ 1.13 million Americans, an increase of 52,000 in 2018. Most of this increase was a result of the resurgence of oil and gas production in the U.S. While some advocates for aggressive action on climate change may see the growth of domestic oil and gas production as a threat, I see it as an opportunity that affords us the economic stability to plan the transition to a low carbon economy over the next thirty years without the disruption that spikes in fossil fuel prices or lack of availability would cause. Just remember the problems that accompanied the 2007–8 spike in oil prices to $140/barrel. Agriculture, manufacturing, and transportation, worldwide, faced serious consequences.

The luxury of our current energy abundance also allows us to attack the much more difficult problems of reducing GHG emissions from the industrial, agricultural, and transportation sectors without dealing immediately with the social dislocation that would be caused in those sectors and in more rural parts of the country, all of which are more heavily dependent on fossil fuels.

Although most fuels' production in the U.S. is fossil today, it is important to note that the 2019 USEER identified over 106,000 Americans who work in renewable fuels, an increase of almost 2,300 jobs.

Electric Power Generation (EPG) employed 876,000 people in the US in 2018, a decline of some 8,000 from 2017, but roughly 8,000 more than in 2016. The declines were clustered in the solar, coal and nuclear generating technologies and were partially offset by gains in natural gas, wind, CHP, and geothermal. While the number of overall jobs in EPG has remained relatively stable, the fuel source of those jobs has changed dramatically and resulted in significant reductions in GHG over the last decade. Today, 640,000 people, or roughly 73% of the EPG workforce are employed in low emissions technologies—including wind, solar, geothermal, nuclear, hydro, combined heat and power, biomass, and low emissions natural gas. In addition to including almost ¾ of the workforce, these technologies produce almost 60% of our country's electricity. 242,000 work in the solar industry, 111,000 in wind, and 63,000 in nuclear generation and 66,000 in hydro, our four principal zero emissions' technologies. This is the clearest proof I know that the transition to a low carbon economy can be done in a way that produces jobs, ensures reliability, and provides affordable electricity to consumers and business.

However, it would be misleading not to point out that this success is dependent upon the continued production of natural gas, the largest single source of generation in the country today and the employer of over 270,000 Americans on the extraction side alone. Another 352,000 work in the distribution and generation side of natural gas, for a total of almost 625,000. The shift of generation fuels from coal to natural gas has been one of the most consequential steps to reduce GHG emissions in both the electrical and industrial sectors over the last decade. The flexibility of natural gas has also been an important factor in accelerating the deployment of variable renewable energy technologies like wind and solar.

Our energy infrastructure workforce—the men and women who build and maintain the fuels' and electricity transmission, distribution and storage systems—is the scaffolding around which the rest of our economy is built. Without the "on time" delivery of reliable and affordable energy every other aspect of our economy would grind to a halt. Today, in addition to a million people employed in gas stations, our energy infrastructure workforce is composed of another 1.4 million Americans who build and service 642,000 miles of high voltage transmission lines, 2.6 million miles of interstate pipelines, and 6.3 million miles of distribution lines, as well as the ports, railway lines, and other essential infrastructure assets. According to the American Society of Civil Engineers, our country's energy infrastructure would get a D+ if given a high school grade. This translates into a $177 billion funding gap over a 10 year period for the electricity system alone. We lose a significant portion of generated electricity to the inefficiency of our grid. Upgrades in the grid are another example of how efficiency investments can directly lead to GHG reductions by simply reducing the need for generation, regardless of source.

Finally, our energy efficiency workforce is critical to the success of any effort to address climate change, and its workforce challenges are key to the successful management of an overall energy workforce in transition. With 2.35 million workers, our energy efficiency workforce is composed of 55% construction workers, 21% professional and business services, 14% or over 320,000 manufacturing employees, 10% in wholesale trade and other. Our energy efficiency workforce has added over

275,000 jobs in the last three years and is the fastest growing sector of the low carbon economy.

Unlike fuel production and some renewable resources which tend to be geographically specific, our energy efficiency workforce is located in every state in our country. In my home state of Minnesota, there are EE workers in every one of our 87 counties.

It is especially important to note that we are facing a hiring crisis in energy efficiency technologies in our country that is the worst in the entire energy sector. According to our recent survey, 84% of employers in the construction side of EE found it either very difficult or somewhat difficult to hire new employees in 2018. This represented a 5-percentage point jump in intensity over 2017 with 52% of EE construction employers saying it was "very difficult" to hire new employees, citing a lack of experience, training and technical skills as the main reasons. EE employers had predicted 9% job growth for 2018 and yet were only able to grow by 3% last year. The skills' shortage has become critical and addressing it is key to creating a low carbon economy that benefits all working people in America and rapidly reduces GHG emissions.

I want to turn now to one of the key disparities in today's energy economy and one of the great challenges to the successful transition to a low carbon economy. That is the geographic uniqueness of key energy resources. Coal is concentrated in Appalachia, Wyoming, Montana, and the lower Ohio River basin. Petroleum resources are strongest in TX, LA, ND, and OK. Natural gas jobs are clustered in the Gulf Coast and the Marcellus Shale. Solar resources are strongest in the Southwest. Wind is concentrated in the Central Plains corridor. What benefits the deployment of one resource may negatively impact another.

So what are some of the effective job strategies for dealing with the disparities that are inevitable in the transition to a low carbon economy, to minimize dislocation, and maximize opportunity? Here are five key strategies.

First, we need to embrace an "all-of-the-above", flexible strategy toward climate solutions. There is no silver bullet, no single technology, nor one perfect policy that can guide our economy to a low carbon endpoint, guaranteeing CO_2 reductions and a decent job for every American. But we can invest in a range of technologies and options to preserve flexibility and participation by every form of energy and every community during the next decade while we pursue every technological solution—from renewables and battery storage in California to carbon, capture, utilization, and sequestration in Appalachia to small modular reactors in Idaho.

This is the scientifically prudent approach and it is also the economically inclusive approach. It is especially important when we think about how to decarbonize the industrial, agricultural and transportation sectors of the economy which are responsible for almost 70% of total emissions. It also means that our coal and gas dependent communities have jobs and a path forward. It means our rural, industrial communities have a role to play. That agriculture is an ally. It means our coastal communities can look to offshore wind, and our renewables-rich communities can prosper. The low carbon economy doesn't need winners and losers. It needs collaborators.

Second, we need to accelerate our investments in energy efficiency with a special priority on those regions of the country negatively impacted by declining use of fossil fuels. Numerous local clean energy development funds have demonstrated the effectiveness of energy efficiency financing mechanisms as a vehicle to pay for building retrofits through energy cost savings while also creating well-paying construction jobs. Such agencies as the New York State Energy Research and Development Authority, the St. Paul, Minnesota Trillion BTU initiative, the many utility administered programs, PACE and on bill financing mechanisms have all demonstrated this success.

A third strategy is to invest in energy infrastructure. Energy infrastructure is necessary to and crisscrosses every community. It is also closely linked to energy efficiency GHG reductions on the electrical side and to methane emission reductions on the natural gas side. In addition to enhancing resilience and national security, these investments provide access to some of the best jobs in America and provide pathways to lifelong skills and job security. Inevitably, such infrastructure investments lead to broader economic development.

As a former DOE employee and board member of DOE's Loan Program Office, I would be remiss in not stressing the immediate and important role that the DOE Loan Program Office could play in jumpstarting investments in our country's energy infrastructure and creating thousands of well-paying construction jobs and learning opportunities. With $39 billion of unused low interest loan and loan guarantee authority, the LPO could move rapidly into the much needed space of helping to finance America's next generation of energy infrastructure. The Energy Futures Ini-

tiative has provided an analysis of this subject, published in March, 2018, entitled, "Leveraging the DOE Loan Program: Using $39 Billion in Existing Authority to Help Modernize the Nation's Energy Infrastructure" which is attached to my testimony. The LPO could also play a role in supporting the use of regional clean energy lending institutions, accelerating the deployment of energy efficiency technologies.

Both energy efficiency and energy infrastructure investments are applicable for every community in the country. However, by investing, first, in these critical aspects of the energy system in those communities and regions impacted most significantly by the loss of jobs in fossil fuels, we can provide economic development support where it is needed most, a critical choice at a time when new energy technologies are displacing some long-standing energy production systems. The sequencing and timing of how we solve a problem can ultimately determine the support it achieves from our fellow Americans.

Fourth, we need to focus on the manufacturing supply chains that our new energy technologies are creating. Nothing is more frustrating than looking back over the years of American technological innovation and recording the history of American applied research being handed off to other countries for commercialization. Such was the story of wind and solar technologies, developed here in the U.S., before being ceded to Europe and Asia. We do not need to repeat this history with the next generation of low carbon technologies.

Especially with energy efficiency products, such as high efficiency appliances, lighting systems, industrial motors, or water pumps, one of our clear goals, when introducing new regulatory requirements, should be assuring a manufacturing policy that encourages "Made in America." Much of the infrastructure is already in place but we need to nurture it and aggressively support it. The EnergyStar brand, promoted by the U.S. EPA is one of the strongest product marketing brands in the world, recognized as the gold standard for efficiency. Using a new EnergyStar Made in America procurement policy to support the manufacture of "best in class" products in the global economy would be one of the best paths forward to a resurgence in American manufacturing.

EnergyStar not only certifies products, it also certifies commercial buildings, single family residences, and industrial processes. We already have the least carbon intensive steel industry in the world, for instance, and that should be a cause for celebration and recognition. Carbon performance should be a universal procurement standard for government spending in the U.S., similar to what California recently did with its "Buy Clean" standard. Such a policy would provide a significant boost for domestic manufacturing.

Finally, we need to address the workforce development crisis across all energy technologies, but particularly in energy efficiency. During the four years of the production of the U.S. Energy and Employment Report, I have watched with alarm as the reports of employer hiring difficulty have steadily gone upward from 75% in 2015 to 80% in 2016 to 83% in 2017 and finally to 84% last year. At the same time the disparity between projected hiring growth rates and actual hiring rates from employers in key industrial sectors has grown wider and wider.

Consider these examples. In 2016 EE construction firms projected a growth rate in 2017 of 11%, but actual employment in those construction firms declined by 7% that year. Overall, energy efficiency employment still grew by 67,000. Two years later hiring difficulty by these same construction firms had risen to 84% with 52% saying it was very difficult to hire new employees. Employers had projected hiring 10.6% or over 120,000 jobs but the reality of hiring difficulty got in the way and they added only 21,000 jobs. This was a failure of our workforce development system with very real world consequences. From the environmental perspective, millions of tons of CO_2 went into the atmosphere that could have been prevented. But from the human perspective, this represented over 100,000 families that could have entered the middle class with some of the best paying jobs in America.

I want to finish my testimony with some comments about our energy system and job quality in America. We have recently heard much more discussion about income and wealth inequality in America, often from surprising sources. At EFI we recently completed a wage survey of energy sector employment to better understand the effect that technology shifts were having on job quality, access and inclusion in our energy workforce. We expect to publish a full report on this subject later in the spring.

Let me share some preliminary findings with you today. First, with a handful of technology exceptions, our energy and energy efficiency workforce is racially as diverse or more diverse than the American workforce as a whole. Thus, in Fuels, Electric Power Generation, TDS, and EE these sectors of the economy are places where all Americans can feel welcome. In Electric Power Generation and in Transmission, Distribution, and Storage, the workforce is 35% more diverse. Gender equity, how-

ever, does remain an issue. Energy and energy efficiency jobs also pay substantially more than equivalent occupations outside of the energy field. For instance, an electrician working in the electric power generation area gets paid, on average, $1.49 per hour more than an electrician generally, a construction laborer in EPG gets $.95 more. In TDS those premiums rise to $2.66 and $1.70. Interestingly, across a range of manufacturing positions, Energy Efficiency workers earn from $.82-$1.39 an hour more.

Another important factor underlying this wage differential is the higher degree of unionization in America's energy sector. In Transmission, Distribution, and Storage, the unionization rate is almost three times higher than the average private sector rate. In Energy Efficiency it's double, while in Electric Power Generation it is generally higher except in the wind and solar technologies. Fuels production is below the average.

The quality of energy jobs is very often the anchor to the social and economic quality of a community. Consider for instance the relatively rural, isolated nature of most of the communities where America's 90+ nuclear generating stations are located, producing 20% of U.S. electricity, all of it carbon free. The nuclear sector happens to have the highest median wage of any technology in the energy sector. It is not surprising that these employers and their employees are among the most highly valued in any community. Regardless of your personal views on the value of nuclear to our overall energy system, it should be our aspiration that every job in energy in America has the same value to its community that those nuclear jobs do.

I want to close by thanking the Committee again for this opportunity to testify about the importance of America's energy workforce and our collective responsibility to those men and women to ensure their safety and economic security since the rest of our economy depends on them. As I said earlier, the problem of climate change is an opportunity in work clothes. That means it's a paycheck not a layoff slip. With sound economic analysis, accurate jobs data, and a collaborative approach we can manage our path to a low carbon economy by investing in new opportunities and new jobs first before we put old technologies on the shelf.

Thank you very much.

Ms. CASTOR. Thank you, Mr. Foster.

Mr. Harvey you are recognized for 5 minutes.

STATEMENT OF HAL HARVEY

Mr. HARVEY. Thank you, Madam Chair, thank you Ranking Member, and all the other members here. It is a great honor to be here today.

I am an engineer by education. I have decades of experience in finance, in technology, in public policy, and in engineering and construction. And I have come here today to offer options that I think are practical and that will appeal to both sides of the aisle. As honored as I am to address this, I guess, body, I have to stay it is especially important, I have my son with me today. So he can witness my work, but, especially, because we all have a deep obligation to our children to give them a planet as bountiful as the one we inherited. We cannot shirk that duty. My approach in thinking about energy policy is to think about the four qualities that Americans need with their energy. They need affordable, reliable, clean and safe. It is these attributes that are the public policy goals, not a specific technology. And the right kinds of policy can produce those attributes.

Here is the big picture, and it is pretty terrific: It is now cheaper to save the planet than to ruin it. I appreciate the testimony from the Chamber of Commerce, it should have been written 10 years ago, because the technologies are here today. We have had amazing advances in batteries, in electric vehicles, onshore wind, offshore wind, 3-D printing, solar, LED bulbs, industrial control systems, heat pumps and more. And so, it is now cheaper, in many, many

circumstances, to drastically reduce climate change than to keep going with business as usual.

The key missing ingredient is the right kind of policy. We want to reward those characteristics of affordable, reliable, clean and safe, or do we want to protect income and technologies? Let me offer an example. My team analyzed every single coal-fired power plant in America, the economics of them. Three-quarters of them now cost more simply to operate than replacing them within 35 miles with solar and wind. So it is cheaper to take those same locations, those same transmission lines and the same workers, and give them a better job in clean energy than to keep running those old power plants. It is also better for the economy because it saves consumers money.

People worry about reliability with clean energy. The states in America, and this is our great experiment in democracy, that have adopted strong wind energy standards have more—have increased the reliability of their grid. It moves you in the proper direction not the wrong direction.

So let me offer four policy ideas, but also mention in my written testimony, we worked on a comprehensive strategy that I urge you to take a look at. The first policy I would recommend is to require that the Federal Energy Regulatory Commission be a merit-driven, technology-neutral, adjudicatory body required to run the power system at the lowest cost. That seems straight forward and that seems like a bipartisan idea. And in fact, that is the way the FERC has worked for years. But in the last 2 years, they have started to put the thumb on the scale for certain technologies. In my mind, that is a Soviet-era thinking. That is not what America should be all about.

Second, we should set performance targets for our grid. I would argue for 80 percent zero carbon electricity by 2035. This is ambitious, but it is realistic, and it is cost effective. It will save consumers money. If you don't believe me, check out Iowa, or Kansas, or Texas, or Oklahoma, or California, which have different geographies, different policies, different political situations, but are all benefiting from incredible rapid adoption of clean energy technology.

We worked in Texas when George W. Bush was Governor. He signed the first—the second renewable portfolio standard in the country. And it has been a huge success.

The third option I would offer for your consideration is let's make sure America builds the most efficient clean cars on the planet. We need to accelerate the energy efficiency standards and accelerate the transition to zero emission vehicles.

Ranking Member Graves, I have traveled to China more than 70 times. I have worked in a dozen countries on energy policy. And I tell you, they have a lot of bad stuff to fix, but they are working hard on it. And they are moving in the transition to electric vehicles, I am afraid, a lot faster than we are. We don't want to have China on that technology, that should be an American technology, in my opinion.

The fourth recommendation I would offer is to make sure that the affected communities in this transition are treated properly. So think of the coal mining towns in West Virginia, we should have

an environmental restoration project of significant scale, so that the same people in the same communities with similar skills can be part of the solution and can be supported for that. They have helped deliver low cost electricity to this country for 100 years, let's not walk away from that now, let's begin a serious environmental restoration project.

I see my time is running out. Let me offer a concluding thought. My work is organized around solutions, practical solutions, based on economics, based on engineering. But I must have done something horrible in a previous life, because I also have to keep up on the climate science. And I am here to tell you that if we don't act, and don't act rapidly, we will leave a much impoverished Earth to our children. We will walk away from the America we recognize and create FEMA world, and nobody here wants that. So we need to do the right thing and we need to do it rapidly. Thank you.

[The statement of Mr. Harvey follows:]

Federal Policies To Slash Greenhouse Gases
Hal Harvey, et al.,
April 2019

Federal policies could reduce the United States' greenhouse gas (GHG) emissions by at least a third below 2005 levels by 2030, and at least 80 percent by 2050, according to modeling in the Energy Policy Simulator (available at https://www.energypolicy.solutions).

Ultimately, we must get to zero, but this package would be a great start, using only federal policy levers that we believe should have a reasonable chance of passing. This package would also kick-start innovation, opening up further options to drive emissions to zero in the coming years. However, this is a comprehensive package, not a menu from which to select. Only enacting policies that address emissions in every sector creates a reasonable chance to avoid the worst impacts of climate change.

The electricity sector has the greatest emission reduction potential by 2050, given the recommended policies below—the path to zero is relatively clear, and we know the technologies and approaches that can deliver it. The faster we decarbonize the power sector, the more we can use it to decarbonize other sectors—like transportation and buildings, by converting fossil fuel burning to electricity.

The next largest opportunity lies in addressing super-pollutants (methane and fluorinated gases), which tie closely with other policies to reduce emissions from the U.S. industrial sector. Heavy industry produces a large share of U.S. GHGs today, but the path to zero is less clear for industry—policies included here will get us a good start, but more research and development (R&D) is needed to support industry decarbonization.

Major opportunities to reduce GHG emissions via policy also exist in the transportation sector—including a mix of electric vehicle incentives, supporting infrastructure, and strong standards for traditional internal combustion engine vehicles.

Another important chunk of emissions reductions comes from upgrading the energy efficiency of existing buildings and also switching from burning gas or oil onsite to using electricity.

Agriculture also presents emission reduction opportunities, and support for agriculture-related R&D can help identify options to drive additional emissions reductions.

A carbon price adopted at the federally-estimated social cost of carbon would offer additional potential emissions reductions alongside these sector-specific policies.

Finally, the list of policies below includes important enabling policies, such as support for rural Americans in the energy transition, as well as expanded clean energy and carbon reduction R&D.

ELECTRICITY

The electricity sector is currently the second-largest source of U.S. GHG emissions, but it has the clearest path to zero emissions. We have the technology (and it's increasingly cheaper to deploy clean rather than polluting power plants), we have the know-how, we just need to get this moving—and quickly.

Leaning into this sector where we are already making progress will have knock-on benefits for other sectors: A decarbonized electricity system can be used to replace fossil fuels in other parts of the economy, via electric vehicles, electrifying buildings that would otherwise burn natural gas, and electrifying parts of factories that would otherwise burn fuel onsite.

CREATE A 100 PERCENT NATIONAL CLEAN ENERGY STANDARD

A 100 percent clean energy standard for the electricity sector by 2045 [1] is one of the most effective policies for reducing U.S. GHGs. The standard could include all sources of zero-carbon electricity (solar, wind, biomass, hydro, geothermal, nuclear, carbon capture and storage, and any other source of zero-carbon electricity developed between now and 2045). It should include interim targets at least every five years, or better yet, an annual improvement rate of two percent per year from 2020–2045. Special attention must be paid in early years to develop low-cost options for squeezing the last 10 percent of GHGs out of the power system.

EXTEND AND EXPAND TAX CREDITS FOR SOLAR, WIND, AND ENERGY STORAGE

Extending tax credits [2] for solar, wind, and energy storage is another strong mechanism to support clean electricity, particularly if a national clean energy standard is not part of a final policy package. These kinds of incentives help spur the market for newer technologies with great potential, driving sufficient scale to bring down costs and make new options available for Americans. Offshore wind and energy storage are two of these newer technologies, but have huge market potential if they can achieve enough scale to bring costs down just a bit more.

In addition to traditional tax credits, the federal government could address upfront capital costs for clean energy technologies by leveling the playing field with fossil fuel infrastructure through additional financing mechanisms such as Master Limited Partnerships, Real Estate Investment Trusts, Clean Renewable Energy Bonds, and securitization of project debt (similar to how Fannie Mae does this in the housing market).[3]

ISSUE A STRONGER MANDATE FOR FERC TO MODERNIZE POWER MARKETS AND MAKE THEM TECHNOLOGY NEUTRAL

The wholesale power markets regulated by the Federal Energy Regulatory Commission (FERC) were established in an era when coal and other fuel-burning power plants dominated the U.S. electricity system. Naturally, rules and structures were designed with the power plants of the day in mind, but many more options are available today and the power markets must evolve to take advantage of them. FERC should inventory market rules and structures with an eye toward updating them to be truly technology neutral given the swath of new options available today.[4] FERC should also consider complementary reforms to the governance of regulated power markets to ensure decision-making processes reflect today's needs.

The federal government should further clarify that FERC should consider benefits of GHG emission reductions in its gas infrastructure and electricity market design rulemakings. In the absence of a clean energy standard, the federal government should articulate its intention that FERC-jurisdictional markets assist state efforts to reduce GHG emissions.

SPUR TRANSMISSION: GET MORE FROM THE EXISTING SYSTEM, SMOOTH THE WAY FOR MORE

Transmission is the platform that allows our nation's electricity system to function. As renewables provide increasing amounts of the U.S. electricity supply, we need to move it from the places with the greatest solar and wind resources to the

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[1] Note that it would be useful to structure this as an incentive-driven race to the top; in the past, state officials have balked at federal requirements on their electricity mix.

[2] Note that taxable cash incentives are much more efficient than tax credit structures—with some analyses suggesting the same federal dollar could achieve twice as much in the form of a taxable cash incentive as in the form of a tax credit (see https://climatepolicyinitiative.org/wp-content/uploads/2012/09/Supporting-Renewables-while-Saving-Taxpayers-Money.pdf). The financial efficiency of tax credits may even decline further given recent tax reform, as large businesses have less tax appetite and the already-tight market for tax equity will likely become even tighter.

[3] For more on what would need to be done to make these structures as useful as possible, see: https://www.nrel.gov/docs/fy14osti/60413.pdf.

[4] See this paper we wrote: https://energyinnovation.org/wp-content/uploads/2017/10/A_Roadmap-For-Finding-Flexibility-In-Wholesale-Power-Markets_FINAL.pdf.

places where people and businesses need to use it. We can do that by getting more out of our existing system,[5] and by adding new lines.

The federal government could build on the National Interest Electric Transmission Corridors[6] to overlay priorities for GHG reduction goals, aligning transmission incentives with GHG objectives, then partner with states to increase capacity on existing rights of way or build new lines. President Lyndon Johnson provided a model for this in the 1960s with the build-out of the Pacific Intertie.[7] Texas also provides a model by pre-approving and building out transmission to "Competitive Renewable Energy Zones" where clean energy resources are abundant. Market mechanisms can then select the lowest cost projects to build clean power in those zones.

While transmission allows electricity to travel across space, energy storage can allow electricity to travel across time, alleviating congestion on transmission lines. The federal government could direct FERC to consider establishing structures to plan and pay for energy storage in a similar way to transmission.

CREATE A NATIONAL DEMAND RESPONSE PROGRAM

"Demand response" is the term for when consumers and businesses shift when they use electricity to take advantage of low-cost or low-emissions sources. This can reduce the need to build costly new power plants, and can help get the most from renewable energy. A national program focused on scaling demand response could kick start the market—perhaps via pay-for-performance matching funds for states or municipalities that establish programs. Loans may also be considered since well-designed demand response programs should pay for themselves in short order.

SUPER POLLUTANTS

Bolstering efforts to reduce carbon dioxide with programs to address methane and fluorinated gases ("F-gases") is an efficient way to drive near-term reductions in U.S. contributions to climate change. Per molecule emitted, methane warms the climate at least 28 times more than CO_2, and F-gases can be thousands of times stronger contributors to climate change.

RAPIDLY PHASE OUT F-GASES BY RATIFYING THE KIGALI AMENDMENT AND GIVE EPA AUTHORITY

Ratifying and implementing the Kigali Amendment to the Montreal Protocol would create a requirement to reduce F-gas consumption in America. The U.S. Environmental Protection Agency (EPA) has already attempted to regulate F-gases under the Significant New Alternatives Policy (SNAP), but the ruling was remanded. Expressly directing EPA to regulate these gases, with the flexibility to use other approaches beyond SNAP, would allow it to move forward with requiring the use of lower GHG-emitting substitutes. U.S. companies would be at a competitive advantage with a strong new F-gas phase-out policy, as they are the primary manufacturers of the chemicals that could substitute for climate-warming F-gases.[8]

SET A STEADILY DECLINING STANDARD FOR METHANE EMISSIONS FROM OIL AND GAS, INCLUDING EXTRACTION AND DISTRIBUTION

The federal government could strengthen Obama-era standards for methane leakage, methane leak detection, and mitigation systems to push methane leakage rates toward zero. A 2050 target of zero leakage throughout the system, along with strong interim targets, will encourage the natural gas industry to invest in the system upgrades and monitoring equipment necessary to significantly cut emissions. Canada's methane rules could serve as a template for early action—it aims to reduce methane emissions from the oil and gas sector 40-45 percent from 2012 levels by 2025.

The federal government could dedicate resources to measuring methane leakage, include leakage estimates into GHG inventories, and reward gas utilities for targeting leakiest equipment first.

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[5] Dynamic line rating gets more out of the system than existing practices in much of the country (for more, see https://issues.nawindpower.com/article/using-grid-weve-got). Where needed, we can beef up transmission capacity on existing rights of way.

[6] See this factsheet from the Department of Energy: https://www.energy.gov/sites/prod/files/edg/media/NIETC_Fact_Sheet.pdf.

[7] See this article from the board chair of PJM, the nation's largest electricity market: http://www.orkas.com/the-future-of-electric-transmission/.

[8] For example, the case brought against EPA resulting in remand of SNAP was brought by Mexichem Fluor, Inc., a Mexico-based chemicals manufacturer.

INDUSTRY

Federal options for reducing industry sector GHG emissions are less well-established than some of the other economic sectors. However, it is very important for any comprehensive climate plan to address emissions from the industry sector, as industry produces about as many GHGs as the whole U.S. transportation sector today, as well as a large share of the projected remaining GHG emissions in 2050. The U.S. needs a plan to address this sector and develop further options to drive down emissions. The following policy proposals are a good start.

ESTABLISH CARBON INTENSITY STANDARDS FOR CEMENT, STEEL, CHEMICALS, AND NATURAL GAS AND PETROLEUM SYSTEMS; ALLOW TAX CREDITS FOR SOME SHARE OF UPGRADE COSTS

New emissions intensity standards could drive industry energy and emissions savings.[9] A program that sets new output-based standards every few years based on the top industry performers could drive a race to the top and encourage continuous improvement in U.S. factories. Standards could be set based on emissions or energy per unit of output (e.g., CO_2 per ton of cement or BTU per ton of ethylene produced). Tax credits based on performance could be made available to businesses that invest to meet new standards. This policy could be coupled with a border adjustment to level the global playing field for U.S. industries.

CREATE A FEDERAL "BUY CLEAN" PROGRAM

A federal "Buy Clean" program would set standards for cement, iron, steel, and other products used to build federally-funded infrastructure, based on the emissions intensity of those inputs. A model policy is in place in California (Assembly Bill 262), which includes suppliers' emission intensities in government procurement decisions.[10] The federal government could ensure a national program considers material substitution opportunities (e.g., using timber instead of steel for buildings less than 20 stories).[11]

INCENTIVES FOR INDUSTRIAL COGENERATION AND WASTE HEAT RECOVERY

New incentives for industry facilities to cogenerate electricity and heat, and to use waste heat, would improve the efficiency of U.S. factories. Incentives for cogeneration should not be offered for coal-fired industrial equipment.

INCREASE INCENTIVES FOR CARBON CAPTURE AND STORAGE AND PROVIDE FINANCING AND TECHNICAL ASSISTANCE

Carbon capture and storage (CCS) could be a critical part of decarbonizing the industry sector. Section 45Q tax credits were recently increased and expanded to cover smaller industries, but these tax credits could be increased to kick-start industrial sector CCS, which has fewer decarbonization options than the electricity sector. Complementing these tax credits with loan guarantees and technical assistance would help industries access the capital and expertise needed to install CCS, which is a relatively new technology with high upfront capital costs and little monetized payback.

BUILDINGS

Improving America's buildings can result in better comfort and energy service for citizens and business owners, while also reducing greenhouse gas emissions. Buildings can be a tough nut to crack since there are so many dispersed decision-makers, but that is precisely the reason this sector provides a way to reach voters with something tangible that can make their lives better.

INCENTIVES FOR BUILDING ELECTRIFICATION AND EFFICIENCY RETROFITS, WITH SOME IMPORTANT EXCLUSIONS

Buildings can decarbonize by using energy more efficiently, and then converting essential uses to clean energy. Because the majority of existing U.S. buildings will

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[9] Note that this has not been done in the U.S. to date, but other countries have used this approach with some success. For example, see Ontario, Canada's proposed industry performance standards: https://prod-environmental-registry.s3.amazonaws.com/2019-02/EPS%20Regulatory%20Proposal%20%28EN%29_0.pdf.

[10] See https://buyclean.org/2017/10/16/gov-jerry-brown-signs-buy-clean-law/.

[11] See http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_FullReport.pdf.

still be standing in 2050, the federal government must find ways to incent retrofits combining appliance electrification, efficiency, and on-site clean power generation (e.g., rooftop solar) if practical. By and large, existing buildings could be much more efficient, but the upfront cost of upgrades dissuades building owners.

A national program with financial incentives including low interest loans or on-bill financing for building retrofitting could significantly accelerate the pace of retrofitting; current programs vary in their effectiveness but generally reach only a fraction of one percent of eligible customers each year.[12] A national program to target a package of decarbonization retrofits in one percent of U.S. homes per year would be reasonable and in line with Germany's retrofit rate.

Such programs should encourage efficiency retrofits to include electrification and clean on-site generation, reducing the total cost of all decarbonization measures. Programs should also encourage pay-for-performance, increasing the value of efficiency measures to the grid.[13] On the flip side, gas appliance retrofits should not receive federal funding; while they reduce emissions in the short term only in coal-heavy states, they also lock in gas consumption for the 15–20 year appliance lifespan, and create upstream methane leakage.

Like renewable energy 20 years ago, all-electric retrofits come at a premium today, but hold huge long-term potential for cost and carbon reductions. When contractors get in the door of a building for an efficiency retrofit, they should also seize the moment to drive electrification. Building electrification incentives could include tax credits for demand response-enabled heat pumps for space and water heating and cooling (which in addition to replacing natural gas, enable a huge efficiency improvement for space and water heating), heat pump clothes dryers, and electric induction stoves, at the point of sale.[14] The federal government can also increase customer access to these technologies by encouraging utilities to finance them on customers' bills.[15]

Electrification-induced efficiency improvements of this kind have a knock-on benefit of lowering household energy costs while delivering the same comfort and service. In addition, as more of these products are deployed, costs are likely to decline. A higher incentive could be offered to electrify buildings with oil-fired space and water heating, which is more polluting and less efficient than natural gas. To measure progress, the federal government can set a target for the carbon footprint of the U.S. building stock (e.g. 50 percent below 2020 levels by 2035), and delegate authority for sizing the incentives to the U.S. Department of Energy (DOE) to achieve the target as cost-effectively as possible.

DIRECT DOE TO ACCELERATE THE STANDARDS PROCESS FOR APPLIANCES AND EQUIPMENT

DOE has a strong appliance and equipment standards program, but it is underfunded and years behind schedule in keeping standards up-to-date. This may sound like a small opportunity, but it can deliver energy savings, cost reductions for citizens, and pollution reduction. Additional funding for this critical program, along with a directive to accelerate this process would improve appliance and equipment efficiency.

REPAIR AND ACCELERATE THE BUILDING CODE PROCESS

The federal government could maintain and promote an advanced model code for states and regions to choose to adopt, and a federal code could even serve as a backstop for the remaining states with no code.[16] A national model code could be based on California's model, where today's most efficient approaches become the standard every seven years and the building code is automatically reviewed and revised every three years. Advanced codes also offer alternative compliance pathways based on performance, rather than the usual list of prescriptions.

Finally, codes may need to be updated to include GHG considerations in addition to efficiency. Codes should support fuel switching in buildings from oil and gas to electricity, and restrict the build-out of new natural gas infrastructure and hook-

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[12] See https://link.springer.com/article/10.1007/s12053-018-9661-5.

[13] https://www.brookings.edu/research/advancing-inclusion-through-clean-energy-jobs/.

[14] It would be important to only offer these incentives for heat pumps that use working fluids with very low global warming potential—otherwise, some of the chemicals in heat pumps can be dangerous for climate change.

[15] https://aceee.org/sites/default/files/pdf/conferences/eeff/2016/Weeks_Session4A_FF16_5.24.16.pdf.

[16] Building codes are adopted and enforced at the state and city levels, but a federal code could act as a model for smaller jurisdictions to adopt.

ups. They should also require building electrical equipment to be sized to accommodate an appropriate level of on-site EV charging.

MAKE FUNDS AVAILABLE FOR STATES AND CITIES TO ADOPT STRETCH BUILDING CODES AND TRAIN BUILDERS AND INSPECTORS

Federal matching funds could encourage states and cities to adopt stronger building codes to make buildings even more efficient. Funds could also be made available to train builders and inspectors, which would allow more regular building inspections and help drive best practices into building construction, increasing the share of buildings that actually adhere to code.

TRANSPORTATION

The U.S. transportation sector has eclipsed the power sector and is now the largest source of GHG emissions. The move to electric vehicles (EVs) is exciting and many policies can accelerate the shift, but millions more fuel-burning vehicles will still be sold, so we cannot take our foot off the pedal of efficiency improvements for those vehicles, even as we electrify. A complementary infrastructure program focused on transit can reduce emissions by supporting alternatives to personal cars and charging stations for electric vehicles of all kinds.

SET AN ANNUAL IMPROVEMENT RATE FOR VEHICLE EMISSION STANDARDS AND MOVE AUTHORITY TO EPA

Vehicle standards (i.e., fuel economy or GHG emission standards) are key to reducing transportation sector CO_2 emissions. Even with aggressive policies to promote EV sales, millions of internal combustion engine cars will still be sold between now and 2050, and efficiency standards can help drive down emissions from these vehicles. Rather than specify a mile-per-gallon target in the future, standards should specify an annual improvement rate, building on existing standards for light- and heavy-duty vehicles. An annual improvement rate of about seven percent per year from 2026–2040 for light-duty and 1.7 percent per year from 2028–2040 for heavy-duty vehicles[17] would enable U.S. vehicles to become super-efficient, while pushing manufacturers to ramp up sales of plug-in hybrid electric and full electric vehicles.

Moving authority over these standards from the National Highway Traffic Safety Administration to EPA would drastically decrease the administrative burden on the auto industry for following these standards.

ESTABLISH A TRANSPORTATION INFRASTRUCTURE PROGRAM FOR PUBLIC TRANSIT, NON–MOTORIZED TRANSPORT, AND EV CHARGING INFRASTRUCTURE

An infrastructure program could help reduce transportation emissions. U.S. cities need improved public transit options and support for a new wave of EVs. The federal government could provide matching funds (or even greater than 50 percent cost sharing) for states or cities that want to invest in EV chargers at public and multifamily buildings, electric buses, electric light rail, bike lanes, and efforts to make cities more walkable. On interstate highways, an exception could be made in the prohibition of commercial activities at rest stops for fast-charging EV infrastructure, and federal funds could support highway fast-charging infrastructure to help make it easier for drivers to go electric.

REPAIR EV TAX CREDITS BY ELIMINATING 200K SALE CAP

EV incentives have been a major contributor to growth in recent years. Incentives should continue to be offered at existing levels by eliminating the current cap of 200,000 credits per manufacturer, at least for the next five years. To increase accessibility for low- and middle-income Americans, the tax credit system should be amended to allow for cash grants at the point of sale.

AGRICULTURE

The U.S. agricultural sector produces about the same amount of emissions as our nation's buildings sector, but the path to zero emissions in agriculture is much less clear. The following policies can help.

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[17] Note these annual improvement rates assume compounding improvements, not a simple division of improvements through a final year.

INCREASE INCENTIVES FOR AGRICULTURAL PRACTICES TO REDUCE GREENHOUSE GASES

Increased incentives can expand low-GHG agricultural practices, such as low-till methods, cover crops, and water conservation. Conversion to these practices may have high upfront or ongoing costs as well as some loss of revenue, so government incentives can encourage farmers to adopt these practices. The federal government could fund a national experiment to explore whether farmers could be paid directly for increasing the carbon content of their soil.

INCREASE TECHNICAL ASSISTANCE FOR PRECISION AGRICULTURE DEPLOYMENT

The federal government could increase technical assistance for deployment (e.g., farmer-to-farmer workshops) of precision fertilizer, soil supplements, and other practices aimed at reducing costs, chemical input, fertilizer, and soil erosion. Government assistance in the form of incentives and cooperative formation can also help increase precision agriculture deployment.

FUND R&D AND IMPLEMENTATION OF COW METHANE EMISSIONS REDUCTIONS

Cows are a major source of agriculture sector GHG emissions, but the best management practices typically suggested are rotational grazing—which creates struggles with accurate deployment and scalability—and expensive feed change. New R&D is needed for improved options.

CARBON PRICING

CONSIDER A HYBRID CAP-AND-TRADE/CARBON PRICING SYSTEM

Carbon pricing would create an additional incentive to decarbonize the economy, particularly the electricity and industry sectors. The federal government could consider establishing a hybrid cap-and-trade system with cap levels reflecting scientifically based targets, a price floor and ceiling to manage price variability, and a significant investment of revenue in reductions from sectors that respond less to price changes (such as transportation, buildings, and agriculture). Another option is a hybrid carbon tax, whereby the tax level varies based on progress reducing emissions.

An important caveat: Existing sector-specific policies should be not discarded in favor of carbon pricing. Rather, carbon pricing should be used as a complementary policy to help achieve additional emissions reductions. It is not a substitute for performance standards.

RURAL AMERICA AND THE ENERGY TRANSITION

Federal support for rural Americans can be very powerful. These supports include taking care of frontline communities where polluting energy infrastructure has made an impact over the years, as well as sharing the new energy economy's benefits with those who host its infrastructure.

MATCHING FUNDS FOR RURAL COMMUNITIES HOSTING ENERGY AND TRANSMISSION INFRASTRUCTURE

To the extent that new energy and transmission projects include a payment to local communities for hosting infrastructure, a federal matching fund could be created to help support these communities. This can compensate communities and increase public support for these projects.

FEDERAL FUNDS FOR TRANSITION SUPPORT FOR COAL MINERS AND POWER PLANT WORKERS

The clean energy transition will result in fewer Americans working in coal mines and coal power plants. The total number of Americans working in these industries is already relatively small roughly 50,000 Americans are employed in the coal mining industry [18]—so a federal fund would not need to be large to assist communities and individuals through this transition.

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[18] See https://data.bls.gov/timeseries/CES1021210001.

CREATE INVESTMENT INCENTIVES FOR CLEAN ENERGY IN COAL AND FRACKING COMMUNITIES

Local clean energy resources are cheaper than keeping two-thirds of U.S. coal plants running,[19] and can sustain economic development through the clean energy transition. Incentives for clean energy manufacturers and developers to invest in communities that have historically hosted fossil fuel infrastructure can help those frontline communities during this transition. New investment can help create jobs and reinvigorate local economies affected by the transition.

HEALTH CARE FOR COAL MINERS

Federal support for health care for coal miners can help those most harmed by helping America achieve the economic prosperity we enjoy today.

RESEARCH AND DEVELOPMENT

TRIPLE CLEAN ENERGY AND CARBON REDUCTION R&D FROM $2.5 BILLION TO $7.5 BILLION PER YEAR

The U.S. lags far behind on spending on clean energy and carbon reduction R&D. The budget for clean energy and carbon reduction R&D—note this is not the total energy research budget, but just the share going to clean energy and carbon reduction—should be tripled to at least $7.5 billion per year. Research areas that need more attention include: software advancements to plan and run a zero-carbon grid; opportunities to decarbonize heavy industry; hydrogen generated from clean electricity and used to meet both stationary and mobile energy needs; biochemistry and synthetic chemistry; materials efficiency and advanced recycling; new materials like low-carbon cement, steel, and plastic substitutes; as well as carbon capture and removal.[20] [21]

EXPAND CRADAS

The federal government could support broader use of cooperative research and development agreements (CRADAs) between the private sector and national labs. CRADAs demand commitment from the public and the private sector, and are effective at stimulating private research, patents, and accelerating important technologies toward commercialization.

Ms. CASTOR. Thank you very much. Thank you to all the witnesses for your outstanding testimony.

At this time, I will recognize myself for 5 minutes for questions.

Dr. Liverman, the Intergovernmental Panel on Climate Change said that the global community needs to achieve net zero emissions by 2050 to limit warming, but it doesn't specify the country-by-country reductions. You have heard some of the comments up here that gosh, the U.S. can't do it on its own. But what does the scientific literature say about what the U.S. needs to do in order to achieve that global goal? And what is your response to gosh, throw up our hands because other countries may not be moving fast enough either?

Dr. LIVERMAN. Well, the scientific literature is considerable, looking at different countries' responsibility for emissions, and what criteria one might use to decide what an equitable or a politically feasible response might be. So one of the issues is that carbon dioxide stays in the atmosphere for a number of years. So what we emitted 50 years ago, it is still around contributing to warming.

So there are several alternatives, several choices that might distribute responsibility for emissions. If you use current emissions,

[19] https://energyinnovation.org/publication/the-coal-cost-crossover/.

[20] See: http://www.energy-transitions.org/sites/default/files/ETC_MissionPossible_FullReport.pdf.

[21] On carbon removal programs, see also: https://www.wri.org/blog/2018/12/wanted-325-million-federal-rd-jumpstart-carbon-removal.

then, certainly, China is now higher than the United States. But historically, in terms of accumulated emissions, the U.S. still is the highest. We have done more to contribute to warming than any other country. We also have higher per capita emissions, 20 tons compared to a world average of about 6. So depending on which of those allocation criteria we look at in our research, the U.S. could bear a larger responsibility for emissions than a 50 percent reduction by 2030. But that negotiation is something that is done in the political arena, scientists are just pointing out what the various choices would be and what the implications might be in terms of the fair responsibility of the United States.

Ms. CASTOR. Well, clearly, we are behind the 8 ball, because the U.S. has put off climate action for so long that dramatic transition to the clean energy economy.

Mr. Foster, you say this is an outstanding opportunity to create clean energy jobs and lower utility bills for consumers. Help us prioritize as we look to putting together a report for the United States, and for citizens in the Congress. Where do we start?

Mr. FOSTER. Well, one of the projects that we started when I worked at the Department of Energy was the collection of jobs data on energy jobs and energy efficiency, an annual study that we have continued for the last 4 years. What I think it shows us is that the big bulk of an immediate economic impact on Americans is in the field of energy efficiency. We have an outstanding record, we have 2.35 Americans who work in that area, very heavily dominated by construction, but over 320,000 manufacturing jobs. Many of those manufacturing jobs, making that energy efficient equipment, are located in coal States; six of the top 15 are among those. It is no accident that places where we once mined coal produce cheap energy and led to a manufacturing cluster in all those States, so to speak. So investments, picking up projects like the old 48(c), advanced energy manufacturing tax credit, to spark the growth of manufacturing and clean energy, energy efficiency technologies would be one of smartest things we could do to drive economic development in places that have been negatively impacted.

Ms. CASTOR. And Mr. Harvey, you have laid out some significant recommendations for us. You also have authored a book "Climate Solutions," that is a very good roadmap for policymakers. You highlight that we better get started in the energy sector. Could you elaborate please?

Mr. HARVEY. Certainly. There are four big sectors in American energy, or any country's energy, which is the electric grid, transportation, buildings, and industry. They have separate pathways, although obviously connected, and one needs to have policy for each one that understands the dynamics of that one.

The technology advancement off of the electric grid has been dramatic, and it is now driven so that the lowest cost electricity on the planet is solar and wind. And we have many more options on the way. By the way, I am completely in favor of technology, the more advanced technologies. I want to use what have already right away, and keep developing the next generation.

So the electric grid can be decarbonized at a savings to consumers, so long as the policy is proper designed. And what do I mean by that? This is very important. You need a long-term target

that has high certainty. Companies need flexibility on how to get there. The target should be technology neutral and there should be price finding. It should not be driven by arbitrary dicta. If you do those things, you liberate the free market and all its innovation to find a solution. It doesn't mean you softened the goal at all. It means you create enough of a horizon and enough certainty and enough flexibility that you achieve it at the lowest possible cost.

Ms. CASTOR. Thank you very much. Mr. Graves, you are going to yield to Mr. Carter.

Mr. Carter, good morning.

Mr. CARTER. Good morning.

Ms. CASTOR. You are recognized for 5 minutes.

Mr. CARTER. Thank you, Madam Chair. And thank each and every one of you for being here. We appreciate this. This is very, very helpful to us as a committee, and we all take that very seriously, climate change is real. The climate has been changing since day 1, and protecting our environment is real. We all understand that.

Mr. Guith, I am going to start with you. As Ranking Member Graves mentioned, I read your report as well and found it to be very interesting and very balanced. And I appreciate that. I wanted to ask you specifically about something you mentioned. You mentioned a number of private sector businesses that are already making investments in their own right to fight climate change. Can you just talk a little bit about that and maybe just a few examples?

Mr. GUITH. Absolutely. Thank you for the opportunity. I didn't get a chance to go over it in the oral testimony. But in my written testimony, I highlighted a couple of specific projects that I think are emblematic of what U.S. business has been doing over the last decade. And we feature these in our energy debates program. The most recent one we just—module we just put on our website last week was San Diego Gas & Electric who constructed, what at the time was the world's largest stationary storage facility. It has now been surpassed by one in Australia, but I am sure there will be a race to the top to see who can make the most efficient and, frankly, largest dispatchable battery. Advanced reactor at new scale, it is a small module reactor. It is revolutionary design that can be used globally, and in places where you wouldn't necessarily put a large scale reactor like we use right now. And then, one that is incredibly important, just outside of Houston, Texas, a project being built by a consortium of companies that stands to be the first zero emissions natural gas plant, that would be competitive——

Mr. CARTER. I have actually seen that.

Mr. GUITH [continuing]. With off-the shelf natural gas. That power, yes. It is a great project.

Mr. CARTER. And you bring out some great examples. Let me ask you this: As is often the case in Congress, with the best of intentions, we put in government regulations to encourage these type of things. Do you think that it is possible that the government putting more requirements on these businesses to fight climate change in specific ways could do just the opposite, and that is, it could hinder their ability?

Mr. GUITH. Absolutely. I think, even with the best intentions, American history, and probably the history of democracy globally,

is littered with unintended consequences. I mean, we see State by State, and sometimes even national policies are creating headwind for nuclear power right now. Nuclear power remains the backbone of our emissions-free generation. It is the leading source of round-the-clock baseload generation. I don't think those policies were intended to harm nuclear, but——

Mr. CARTER. Exactly.

Mr. GUITH [continuing]. That is what happened.

Mr. CARTER. And as you point out, quite often that does happen, with all the best of intentions.

At the same time, if we put in policies that—if we allow policies that harm our economy, isn't that going to hurt business' ability to address and to make investments to fight climate change?

Mr. GUITH. Absolutely. I mean having private conversations with many of my members, especially in the generation sector, they have all made significant commitments to emissions reductions over the next 30, 40, 50 years. But they are concerned that specific policies might deny them the capital they need to invest in the technologies they would need to actually meet those commitments.

Mr. CARTER. Absolutely. And let me reach just a little further, we have established the fact that China is accounting for 30 percent of all the emissions in the world, the United States, only 15 percent. But even with China and their international emissions, and what they are putting into the environment, does the business community have a role in working with China, do you think, in trying to reduce emissions?

Mr. GUITH. Absolutely it is a great economic opportunity. The reality is, is that emissions from developing countries, and whether you consider China one or not, are going to continue to rise. And unless we or someone else bring the technologies to bear that are scalable to the extent that we are talking about globally—we are not talking about a single state or a single community in this country, where resources are relatively accessible, we are talking about scalable globally. They are going to keep burning coal. So unless we have a way to capture the emissions from that, we are going to continue to be at a net negative as far as reductions.

Mr. CARTER. Well, again, thank you all for being here. Thank you, Mr. Guith. And again, I can't stress, as I have in the past the opportunity that lies here. We have the brightest minds, the greatest innovators, right here in America. That is why I am so excited about this. I mean, people look at this, the sky is falling. Actually, this is one of the greatest opportunities I think we have had in this country in many, many years, and I look forward to seeing it what results from this.

So thank you very much, and I yield back.

Ms. CASTOR. Thank you, Mr. Carter.

Ms. Bonamici, you are recognized for 5 minutes.

Ms. BONAMICI. Thank you, Chair Castor, Ranking Member Graves, and thank you to our witnesses. We know what we are facing. We have already seen heat waves, droughts, wildfires, surge in extreme weather events, more acidic oceans, rising sea levels, and certainly, the intergovernmental panel on climate change emphasizes that it is time, it is past time to take bold action. And we do, here in the United States, have the ability, and, I submit, the

obligation as well, to be a leader in curbing greenhouse gas emissions. Certainly our commitments under the Paris Climate Agreement are an important first step, but there is so much more that we can do, and we must accept this challenge.

We know it is going to require innovation, leadership and the responsible use of our vast resources. I just had the opportunity to tour the manufacturer of a wave buoy that is going to help tap the power of the ocean.

So, Mr. Harvey, in your testimony you highlight examples of advances in clean energy technology, wind, solar, battery storage. Significant Federal investments in research and development have been critical in developing and deploying new and advanced clean energy technologies, programs like ARPA-E, supporting high risk, high reward energy research that is not being addressed by the private sector.

So I am going to ask Mr. Harvey and Mr. Foster, what sectors would benefit from additional R&D resources and in what other areas would additional Federal funds be effective in spurring innovation and research?

Mr. HARVEY. So thank you for the question. I think it is a very important one. Everybody on this panel, I think everybody in this room agrees, technology is the key to success here. Right now, the United States of America spends less than 1 half of 1 percent of its energy budget on R&D. That is pitiful. That is the wrong number. For IT, it is 10 percent, for pharmaceuticals, it is 20 percent.

More than 10 years ago I founded something called the American Energy Innovation Council, which was about 10 CEOs including Bill Gates, the CEOs of GE, McDonnell Douglas, and a number of other companies. We urge the trebling of Federal R&D. I think if you trebled clean energy R&D from roughly 2.5 billion to 7.5 billion you would create an amazing downpayment on the future.

With that said, there is development of new ideas and then there is deployment. Innovation happens all the way along that. You need a different policy for innovation in the deployment phase. You need large-scale purchase. And in the beginning you are going pay a little more, but over time, you drive the price down. So you are creating options for all of humanity. We have done that successfully with solar, with wind, with many aspects of geothermal, with fracking, with many other technologies. The learning curve, as it is called in scientific parlance, is our friend. But if you let technologies die on the vine before you get to those price reductions, then you fail to create those options for future generations.

Ms. BONAMICI. I appreciate that very much. I also serve on the Science, Space, and Technology Committee, so it is very helpful.

Mr. Foster, climate change, as we know, is affecting our entire economy, and solution must include the creation of good-paying jobs. My other committee is the Education and Labor Committee where we do work on a lot of workforce issues at advocated for on-the-job training programs.

And I know, Mr. Harvey, you mentioned people who work in coal power plants. My grandfather was a coal miner in Pennsylvania. I am sure he worked very hard in that coal mine trying to support his family. He lost his leg and then he died of lung cancer, so he

had severe health problems. So we want to have good, safe jobs for workers, and that needs to be central to a clean energy economy.

So Mr. Foster, you talked about the workforce development crisis across all energy technologies, especially in energy efficiency. And you highlight energy efficiency jobs paying substantially more than equivalent occupations outside of the energy field. So how can Congress better support workforce development in the energy sector in our transition to a clean energy economy? Mr. Foster.

Mr. FOSTER. Well, first, let me just add that in my opinion, there is no technology more important to invest in right now than carbon capture sequestration, simply because we have no other paths to decarbonization in the industrial sector and it is extremely important that we contribute to that. It also has other applications that from a political point of view, I think open up the subject of climate change to a much broader discussion in this country because it then talks about what is the future of coal, what are the future of fossil fuels. If we have that technology it becomes very, very important to otherwise abandoned communities.

In terms of what can be done on the energy workforce crisis, I think a deep look at how our Federal agencies collaborate and coordinate on how they develop curriculum that supports energy efficiency technologies, how the National Science Foundation, how the Department of Education, how the Department of Defense, Department of Labor, and the Department of Energy, all work on how they create a uniform, standard-driven energy efficiency technology that can be spread out around the country to our benefit. That was a project we worked on when I was at the Department of Energy. And I think it is something of extreme importance to solve this crisis.

Ms. BONAMICI. Thank you, very helpful. I yield back.

Ms. CASTOR. Thank you very much.

Mrs. Miller, you are recognized for 5 minutes.

Mrs. MILLER. Thank you, Madam Chair and thank all of you for being here today. We all care about taking care of and protecting Mother Earth.

In the past century, we have seen unparalleled economic growth around the world. This boom is in part because people have access to energy, increased access to affordable electricity to power our homes, our schools, and our places of work correlates directly to the improved quality of life for people all around the world. Any recommendation this committee makes must ensure that we maintain access to affordable energy. Dismantling coal, oil, and natural gas will not only hurt our economy, but it will also make energy less affordable and set society back. I can personally attest to the effect of policy that can decimate an economy.

One of the many aspects that makes our country great is our entrepreneurial spirit. So many of our Nation's small businesses and corporations have taken steps to be good stewards of the environment, and to give back to their communities, without the direction of the Federal Government because it is the right thing to do.

It is a good reminder of what can be done when the government takes a backseat, and lets businesses run themselves.

Mr. Guith, in your experience with the private sector, what is already being done to lower carbon emissions while preserving and promoting our Nation's diverse energy mix?

Mr. GUITH. Where do I begin? If you look across the many commitments that have been made, some of them have been within the companies themselves. There has been billions of dollars invested in greater efficiencies within the manufacturing sector.

If you look at the advent of the shale revolution and what that has meant to fuel diversity, and efficiency, and frankly, emissions. But ultimately, as you pointed out, we have seen great economic growth over the last century. If you look over just the last 40 years, we have seen our own economy grow by 170 percent, while simultaneously reducing the criteria air pollutants by 70 percent. That was driven by innovation, that was driven by science, and that was driven by the entrepreneurial and ingenuity of the business community.

Mrs. MILLER. What technologies can and should be deployed to mitigate carbon?

Mr. GUITH. I think there is a pretty wide consensus across every scientific body that has looked at this that the three core technologies that are essential from a scalability standpoint globally are carbon capture sequestration, whether it is utilization or otherwise, stationary storage. Renewables have made a huge dent in our emissions profile, but until we can bring them to a parity, as far as baseload replacement, they are going to have a glass ceiling.

And then finally, advanced nuclear. I mean, everybody that I have looked at, that has looked at this, all say that those are the three. And, obviously, efficiency is going to continue to be integral to all of them.

Mrs. MILLER. In 2017, the United Sates led the world in the reduction of climate emissions. However, other countries, even those who are signatories to multilateral agreements, are canceling out our efforts. Can you speak to how we can, in America, do—help to counteract what these other countries are doing?

Mr. GUITH. As I mentioned in my testimony, the developing world is projected to continue to have emissions increases, while the developed world is projected to continue to decrease them. Unfortunately, they are not equal and we look—we expect emissions to continue to increase globally on the net.

What can be done is what we are doing now, and that is, investing in the technology to a much greater scale. We have consistently been disappointed with OMB's budget when it comes to innovation and technology. We agree that there is lot more that needs to be done at the Federal level, both from an R&D standpoint, but also from a commercialization standpoint, as well as structurally within the Federal Government itself, to focus on these core technologies. But right now, U.S. business continues to lead the way.

Mrs. MILLER. Thank you.

I yield back my time.

Ms. CASTOR. Thank you very much.

Mr. Huffman, you are recognized for 5 minutes.

Mr. HUFFMAN. Thank you, Madam Chair, and thanks to our witnesses.

I am intrigued and a little bit skeptical about this notion of carbon capture and sequestration that we keep coming back to, and several of the witnesses have referenced. Mr. Foster, I can stipulate that if we have got a natural gas power plant that comes online and is truly zero emissions, because it has implemented cutting edge carbon capture sequestration, that will be a good thing. My understanding is that plan is not yet producing electricity. And my concern is that this notion of CCS has always been that thing just around the corner that we keep pointing to to avoid bolder action in support of clean renewables and efficiency and other things. But I want to, for a moment, imagine that this really is near and deployable at scale. And I guess my question for you is, I get that that is appealing to folks that want to minimize disruption to fossil fuel infrastructure and to fossil fuel interests. But why would anyone do it in the absence of regulations, in the absence of some cap on emissions, in the absence of some price on carbon. It is not going to happen out of the goodness of people's heart. Would you agree with me?

Mr. FOSTER. I would agree with that. From the studies that we did when I was at DOE, it was a combination of baseline policy, combined with forward leaning tax credits. And those things have generally been the combination in driving claim policy forward that I have been the most struck by. So that, for instance, the Clean Power Plan, coupled with the ITC and PTC taxes for wind and solar, along with the new technologies of hydraulic fracking lowering the cost of natural gas, very quickly according to the National Renewable Energy Lab within less than 1 year after the adoption of the Clean Power Plan, market forces had taken over and were driving the reduction of the $C0_2$ emissions faster than policy alone. So I think that combination of things is really the magic spot.

Mr. HUFFMAN. All right.

Mr. Harvey, I think I am hearing you say that if we take our thumb off the scale for fossil fuels, and put in place some of the incentives, like the one Mr. Foster and I were just talking about, either carbon pricing or some caps that begin to move the market towards low emission solutions, that clean energy competes just fine, and, in some cases, actually saves money. Would you elaborate on that, please?

Mr. HARVEY. Yes, absolutely. There is a problem with unintended consequences of regulation, and that's been raised already, and we need to pay attention to that. In my mind, the best way to achieve reductions is to think about public standards. We have public standards so that our meat isn't poisoned, so that our water is clean. You mentioned the Clean Air Act, fantastic unleashing of technology in business innovation, but it came about because of public standards, because we said we are going to emit fewer carcinogens and fewer lung-damaging particulates into the atmosphere. That is what we need in carbon dioxide as well; is set clear public standards, and let the market find the best way to achieve them. Don't choose technology, don't choose prices—that is a communist idea—choose what the public needs and let the market do its job.

Mr. HUFFMAN. Can you give us an example of the standards that might be set? For example, there is a lot of talk about net zero

emissions by 2050. Is that the kind of standard that you could build incentives around?

Mr. HARVEY. It is. Although, I wouldn't argue for that one precisely. There are 30 states now with renewable portfolio standards. The best of them say, "Hit the target, go." I don't care—by the way——

Mr. HUFFMAN. Technology neutral.

Mr. HARVEY. Technology neutral absolutely. I would make it clean energy. I wouldn't make it renewable per se. Every one of those, every single one of those has been hit at a lower cost than projected, and some of them at dramatically lower costs. And by the way, they are not R things or D things, they are both sides of the aisle, these renewable portfolio standards.

So for the country, I mentioned 80 percent by 2035, it is feasible. It would set a clear signal. It creates enough of a time horizon that business can get to it. It would be very powerful.

Mr. HUFFMAN. All right. Thanks.

I don't have a lot of time, but Mr. Guith, I am drawn to the fact that you are saying inaction is not an option. And believe me, I am encouraged by that statement as far as it goes, but my challenge is, I am looking at a couple of decades of action by the Chamber here in Congress and elsewhere that is all about preventing action on addressing climate change.

In 2007, you spearheaded the defeat of a very modest climate bill, Lieberman-Warner; you spearheaded the opposition to Waxman-Markey. You turned around, you targeted Members of Congress that voted for that climate solution. In the next election, you defeated them. And when your allies came into power, they have done nothing for a decade on this issue, and you were just fine with that. I guess what I am trying to understand—oh, and you also funded studies that attacked the Paris Climate Agreement and Donald Trump cited those studies, even though they have been debunked by independent scientists. So after all of this effort, you have put in defending the status quo and preventing climate action, as you testify today telling us that inaction is not an option, has there been a change in the Chamber's position?

Mr. GUITH. No. I mean——

Mr. HUFFMAN. Well, that is really what I was asking. And so reserving my time—reclaiming my time, I want to urge you——

Ms. CASTOR. The gentleman's time has expired, and I think we will be able to get back to that issue. So at this point, we will recognize Mr. Griffith for 5 minutes.

Mr. Armstrong will be recognized for 5 minutes.

Mr. ARMSTRONG. Thank you. I take a little exception with the talk that carbon capture isn't feasible. We are dealing with whether it is ELM cycle research, we have a thing called Project Tundra in North Dakota. We have great partnership between the coal industry, the wind industry, the oil and gas industry, and utilizing it because we have—it is North Dakota, but we have some advantages of geography in that they are both there, and not to mention up in the Weyburn Field in Canada has been doing this now for over a decade. So as we continue to work forward with that, I—Americans want clean air, they want clean water. And sometimes, I think we get into a situation where our policies get counterintu-

itive based on politics. And I don't think there is a better answer than that than pipelines. Transportation is obviously one of the lead drivers in carbon emissions, whether it is trains, whether it is cars, whether it is anything, it is not as safe to move product on rail or on the roads as it is in pipelines. But more importantly, we are trying to move natural gas through—it would be nice to get a quorum on FERC, that would be pretty good moving forward. But we try, moving our gas to the east coast, we end up having a really bad winter. Carbon emissions actually go up, because State water laws trumping FERC citing on a pipeline, and so we are using heating oil instead of natural gas to burn. And I think we do this a lot. Perfect is the enemy of good when we continue to have this conversation. So—and just with the Bakken shale revolution in North Dakota, we have invested $12 billion in gas infrastructure. We probably need another $5 or $6 billion more. So as we continue to capture carbon from North American Coal, or the Wolf Creek station, all that is going to do without the infrastructure is—I mean, it is still better. We are capturing the carbon, but we are producing more oil and gas, and we don't have the infrastructure in place to process the gas, and then we run into these kind of issues.

So I guess my question for Mr. Foster, you were the one that talked about carbon capture, what incentives, what advantages can we do so—and I agree with you, it is clean energy, so we can do this in a realistic manner that is allowing industries to compete and also protect the reliability of the grid.

I mean, that is a part of the conversation I don't think we have enough, is that given certain storage limitations and weather limitations, if you live in a State like mine where it is 35 below for 45 days in a row, and windmills don't turn if it is more than 20 below, we have to have reliable energy. And one thing you can't do with a coal plant is just turn it on and off very quickly.

Now, there is some quick combustion engines with natural gas and we can do those things. So how do we really truly incentivize—I mean, we do some stuff with our research arm at the EERC and do a lot of projects, but from a Federal level, how do we not pick winners and losers, and just start talking about whether it is sequestration, enhanced oil recovery, and those types of things.

Mr. FOSTER. I believe that a properly constructed Federal clean energy standard, coupled with improvements to the 45Q tax credit, would provide the kind of architecture to help make carbon capture sequestration more commercially viable in the electric sector. But beyond that, I think it is absolutely critical that we drive the cost of deployment of that technology down so it can be usable in industrial applications, because we have no other way to remove emissions from blast furnaces and steel mills, or from cement kilns, or a host of other industrial applications that are going to be needed the world over. So what better economic driver than to be the leaders in producing, applying, commercializing this technology across all its different uses.

Mr. ARMSTRONG. To understand how this works on the ground sometimes, I mean, innovation happens in really interesting places. So we have an ethanol plant that is immediately located next to a coal plant, and they use the coal plant to heat the ethanol plant.

So they are capturing, they are increasing efficiencies, they are driving down the cost; instead of a waste product, now they are creating two different things.

I will have a question for Mr. Guith. How do we do any of these things that doesn't just export our pollution? If we are going to go back and ban the export of oil, ban the export of LNG, ban the export of coal when we are dealing with developing countries and doing those things. I mean, if we are serious about this conversation, isn't the conversation also have to include that part of the conversation? Because the last thing we want to do is export our pollution to countries that don't have the regulations we have here.

Mr. GUITH. It is not just the production side, it is on the consumption side, too. I mean, we know full well that climate change is a global issue. And if it is not addressed globally, it is not going to be addressed. If we don't have technologies in place that the rest of the world can use, whether it be sequestration or otherwise, then we are going to continue to see emissions rise.

And I would also point out, to follow up on Mr. Foster's answer, right now, the USE IT Act is an incredibly important regulatory change that has tremendous bipartisan support in the Senate, and hopefully, we will see it passed there and come over here to help facilitate greater use of sequestration.

Ms. CASTOR. Thank you very much.

Mr. Levin, you are recognized for 5 minutes.

Mr. LEVIN. Thank you, Chair Castor, and thank you to our witness for providing such thorough testimony. Many of your statements make it clear that the planet is heading towards huge costs associated with climate change. However, it is heartening to see you have done a lot of work to chart the best path forward that can help the United States and the rest of the world to avoid those costs.

Dr. Liverman, I would like to begin with you, and also begin by saying my wife is a proud University of Arizona graduate. She would be very mad if I didn't offer Bear Down. In this committee, we have discussed that there will be a significant financial cost if nations, including the United States, don't take action on climate change. So I would offer that any recommendations the committee makes must be compared to that baseline.

In your testimony, I was struck when you said that limiting warming to 1.5 degrees Celsius rather than 2 degrees could avoid up to $38 trillion, that is with a T, $38 trillion worldwide in damages by the end of the century.

On this figure can you estimate how many dollars of those damages might take place in the United States?

Dr. LIVERMAN. The IPCC didn't look at that, but the U.S. National Climate Assessment did provide some figures. They suggested that if warming continues, that damages could be up to .6 percent higher, if we go up 2 degrees in the U.S. And that would be 2.3 percent of GDP per degree of warming. So if we continue to warm, if we don't act, it will have a significant impact on our GDP.

Mr. LEVIN. So it would be terrific if you could track down the number in trillions of dollars in direct economic impact, the cost of inaction of the United States and provide that to the committee.

Dr. LIVERMAN. I would be happy to do so.

Mr. LEVIN. Thank you.

Mr. Harvey, in fairness to my wife, I notice you went to my alma mater, Stanford University, so go Cardinal. I was interested to read your finding that multiple midwestern States that derive more than 25 percent of their generation from wind power have more reliable grids than their neighbors that don't.

This week, you are probably aware the House is voting on a bill that would keep the U.S. in the Paris Agreement. And I have offered an amendment to that bill underscoring the fact that cleaner and more reliable forms of energy like wind don't necessarily mean less reliability or higher costs. In fact, often the opposite is true.

Could you elaborate on how wind power and other renewables integrated into the grid of future, don't necessarily equate to higher costs or less reliability.

Mr. HARVEY. Certainly, Congressman Levin, and thanks for the opportunity.

I studied power systems planning in my graduate program in engineering at Stanford. And we were taught to turn on power plants in ascending economic dispatch order to meet whatever the demand was, and that people still refer to baseload power, shouldering power and peaking power. That paradigm is giving way to a new management strategy, which is system optimization.

So a grid operator should have a whole suite of resources at his or her fingertips, ranging from the conventional power plants to renewable energy, to demand side opportunities as well. And then wheeling power across large distances. The more options you have, the more robust your system is. If something goes down and you have a good transmission line, you can bring in electricity from another part of the country. When it is freezing cold in North Dakota, it is probably reasonably warm in Arizona. When San Diego has a peak demand, Seattle doesn't and vice versa. And so, by hooking together heterogenous systems and heterogenous power supply and optimizing across the suite, you create a much more robust system and a much more reliable system. It is what other industries are used to doing, the electric power industry is just learning to do that.

I will just mention one last word, the head of the California Independent System Operators, Steven Berberich, is somebody you should consider as a witness, because he is running one of the largest grids in the fifth largest economy in the world, and he is pushing into these frontiers and he is not breaking a sweat.

Mr. LEVIN. I think a field trip to Folsom would be great for the committee to see CAISO.

Mr. Guith, I noted your mention of a San Diego Gas & Electric project. And I commend the work at SDG&E, that is in my neck of the woods. But I note that it didn't happen in a vacuum, it happened only after tough regulatory oversight by the California Public Utilities Commission. I wanted to turn to the Paris Accord and get your take on it for just a minute.

I noticed the Chamber has a position saying, and I quote, "The Chamber believes in an effective climate policy should encourage international cooperation," end quote. And also, quote, "The United Nations Framework Convention on Climate Changes Paris Agreement established a comprehensive framework for international ac-

tion," end quote. Mr. Guith, do you believe the United States should stay in the Paris Climate Agreement?

Mr. GUITH. I think the business community has been pretty clear that United States needs to remain at the table internationally, and that includes the Paris Agreement itself.

Mr. LEVIN. Great. I agree and every member will have the opportunity to vote this week to keep the United States in the Paris agreement when H.R. 9 comes to the floor.

Thank you.

Mr. GUITH. But if I may, though, the legislation is not just about Paris. It is also about the commitment and how by we get there. That is a completely separate issue.

Mr. LEVIN. Well, I find any discussion of H.R. 9, or questioning of H.R. 9, hard to reconcile with the Chamber's position. I actually think it is quite consistent, and I think my colleagues across the aisle will agree if they take the time to read the legislation. I thank you for your time.

Ms. CASTOR. Thank you, Mr. Levin. Mr. Griffith, you are recognized for 5 minutes.

Mr. GRIFFITH. Thank you, Madam Chair. I have to respond. I read the legislation, and I am not voting for it. So there.

All right. Mr. Foster, thank you so much for being here today and thank you—you are probably the only person on the panel today who has actually been to my district. And it was one of those rare moments when while we didn't agree on everything, Secretary Moniz sent you and a team down to see what was going on in coal fields. I greatly appreciated that. We had a seminar as you recall at the University of Wise, University of Virginia at Wise. And then you all went over to a high school in one of my poorest counties, Dickenson County. My district, for those of you who don't know, abuts to West Virginia, Kentucky, North Carolina, and Tennessee. And we have a significant coal mining investment in part of the district, it is a very large district. And so I was very appreciative of your comments on page four of your written testimony that says we need—first we need to embrace in all-of-the-above flexible strategy toward climate solutions. There is no silver bullet. You said this in your oral testimony, too. No single technology, no one perfect policy, which is why I believe we have to continue to invest in research. I would suggest when—I appreciated you both pronouncing Appalachia, for those of us from central Appalachia, correctly. And for recognizing there are some things we can do in Appalachia, one that was not on your list because we hadn't really thought about when you all were down to visit, is close loop storage inside of a coal mine using the water. Obviously there is nothing living down there. We bring the water in from outside, there is not an environmental consequence, and we can use that as a giant battery sitting in the same areas. Mr. Harvey said we want to put some of the jobs in the area where the jobs are going to be lost, and my district has suffered heavily.

Further, I would also have to say that one of the things we talked about at that seminar was the fact that we are going to continue to use coal. Everybody today has been talking about the grid and electricity. A large amount of the coal out of my district makes steel, and I know you have a lot of interest in steel as well having

worked with the unions in that industry. And so, we are going to continue to mine that high quality coal, and we have to find ways to make sure that the American public understands that not every coal is equal to other coal, but a lot of the coal around the world is dirtier than our coal. And we have to come up with new research and ways to do that.

Now, I am excited and will tell you that one of the participants there—and you heard the testimony from Dr. Yoon at Virginia Tech—they just have taken some of their technology and they were looking at rare Earth minerals, and separating that from the carbon in central Appalachia. But they also can make poor coal better. And so they have licensed that technology to steel plants in India, and I think this is how we solve some of these problems, so that they can take that poorer coal that they are mining in India, and upgrade what they are doing because they are going to make steel.

Other nations, particularly in the developing world, they are not going to impoverish their people because we have decided we don't want it to be warmer. No matter what the consequences may be, they are not going to have their people living in the dark or living in poverty. But if we can get technologies that we can then license with these two steel mills that they have licensed their technology are going to do is lower the carbon footprint, because even in the developing world they want to have jobs, they don't want to be impoverished, but they also want clean water and clean air. So this is where I think we can find the win and I appreciate you saying that.

And I am concerned, and I will give you an opportunity to give me some help, that the DOE's loan program that you worked with, and you said in your testimony, there were 39 billion of unused low interest and loan guarantees authority that could move rapidly to help finance some of this research that I am very positive about. Tell me why aren't we using that? What can we do to speed that up?

Mr. FOSTER. Well, I submitted, along with my testimony, a research paper that had been done by the Energy Futures Initiative about a year ago, and a whole range of suggestions on how the loan program office could be applied, particularly to energy infrastructure investments, and a variety of other issues like that. I do think with the budget constraints that Congress may have on it, this is authorized $39 billion worth of loan guarantees, and low interest loans that could be applied without further authorizations.

So, I think looking deeply at ways in which the loan program office could be used to accelerate additional technologies, particularly energy infrastructure, look at the research paper we did, and we strongly encourage the committee to investigate that.

Mr. GRIFFITH. I appreciate that.

Mr. Guith, you heard my spiel on developing countries. What can we do to increase their use of technologies? Because they are going to continue to use fossil fuels, we know that. In fact, the World Bank said we are not going to lend any more money for building coal-fired power plants, so China is investing all over the world, particularly in Sub-Saharan Africa, in building new coal-fired power plants. What can we do to encourage these countries to use the new technologies and to make it cleaner?

Mr. GUITH. That is a great example right there. I mean, the technology that the Chinese are financing is subcritical, and so you have more emissions.

Mr. GRIFFITH. Subcritical means poor?

Mr. GUITH. Yes. If the United States would have remained as part of that financing mechanism, we would have been using ultra critical technology, and, therefore, lower emissions. But ultimately, we need to develop and commercialize the technology. If we make it available as we have so many technologies that we are using right now, the rest of the world will use it. But the rest of the world generally, especially developing world, does not have the resources that we have.

Mr. GRIFFITH. Thank you.

Ms. CASTOR. Thank you very much. Mr. Casten, you are recognized for 5 minutes.

Mr. CASTEN. Thank you, Chair Castor. Thank you so much to the panel.

I want to focus my comments on—the question is on economics, and I just want to start with something that is, I think, non controversial, but too rarely said, and that is that fossil fuel is an inherently high marginal cost source of energy relative to every other option. And when you use less fossil, you reduce less CO_2 and you save money. It is not complicated, but we don't mention it often enough.

The one exception, of course, is in the extractive industries, and the jobs in the extractive industries have a rooting interest in higher cost energy. The entire rest of the economy from steel production to bitcoin mining to airline flight attendants has a vested interest in lower cost energy.

Mr. Foster, can you give me a rough estimate of how many jobs have a rooting interest in higher cost energy in the country relative to the numbers that have a rooting interest in lower cost energy?

Mr. FOSTER. Well, I can give you rough numbers of a number of them according to the U.S. energy and employment report. So for the coal industry, which includes their entire value chain it would be about 200,000 jobs; for the natural gas industry, it would be about 650,000; and for the petroleum industry, it would be about 900,000. So if you try to put that in comparison, I mentioned wind and solar, solar if you are looking at the majority time jobs, it is about 240,000 wind. It is about 107,000. You look at the other zero carbon energy, I think I mentioned nuclear is in the range of 63,000, hydro 66,000.

Mr. CASTEN. Is it safe to say that even those pale beside those industries like steel making, all the manufacturing sector, that actually employs the bulk of the economy and has a rooting interest in lower cost energy?

Mr. FOSTER. Well, I think just about every sector of the economy has an interest in lower cost energy. And one of things I found interesting is following how in the era of really unparalleled growth in the United States, we have seen a constantly diminishing share of gross domestic product going to energy. So it is down to about 5.4 percent today of gross—overall of gross domestic product.

Mr. CASTEN. I am sorry to interrupt, but I know we are am tight on time. Is it safe to say that investing in lower marginal cost en-

ergy sources is a net job creator and is net stimulative to the economy?

Mr. FOSTER. That is a very big generalization that I wouldn't necessarily jump to.

Mr. CASTEN. I certainly would, but fair enough. Part of the reason I say this is because I spent 20 years in the energy industry before I got here. And I am of the opinion that the single biggest explanation for the falling CO_2 emissions in the electric sector was the 1992 Energy Policy Act, and FERC order 888, which, for the first time, encouraged us to preferentially deploy lower cost assets, which, oh, by the way, are the more efficient and less fossil fuel intensive assets.

I was delighted to hear your comments on that, Mr. Harvey. And I wonder if you would chat a little bit about what more we might be thinking at, specifically at the FERC level, to better incentivize lower cost production, and to better value ancillary services like voltage stability and other mechanisms to accelerate this transition to cheaper and cleaner energy.

Mr. HARVEY. Representative Casten, you just proved yourself to be an energy nerd, sir. Congratulations.

Mr. CASTEN. Not the first time.

Mr. HARVEY. So the FERC has a very important job to do now, wholesale markets in America are FERC-regulated, but they are not generally FERC-controlled, they are controlled by independent nonprofit associations that are answerable to no one, and that is a bit of a problem.

What happens is, and you are absolutely correct with rule 888, it opens the doors for lowest marginal cost energy dispatch. However, the FERC and other independent markets have the ability to set conditions for those sales, and the ability to reward other attributes, so spinning reserve, ancillary services, capacity factors, and so forth.

Some of those things you need to reward, others of those are basically fake ways to give a lot of money to certain industries, and I am being blunt here, because one needs to be. That is exactly what is it going on right now.

The proper answer is to define those characteristics based on physical and economic need, not based on arbitrary made up numbers. I think the FERC just needs a stronger instruction about what its role is in creating a truly fluid market, a truly liquid market.

Mr. CASTEN. So with the little time I have left, and I really, really enjoyed your testimony, I want to introduce for the record with unanimous consent if I could, climate policy initiative report supporting renewables while saving taxpayer money.

Madam Chair, I would like to ask unanimous consent to enter this into the record.

[The information follows:]

Supporting Renewables while Saving Taxpayers Money

Climate Policy Initiative

Uday Varadarajan
Brendan Pierpont
Andrew Hobbs
Kath Rowley

September 2012

Descriptors

Sector	Power
Region	United States
Keywords	Renewable Energy, Finance, Solar, Wind, Tax Incentives
Related CPI reports	Renewable Energy Financing and Climate Policy Effectiveness, The Impacts of Policy on the Financing of Renewable Projects: A Case Study Analysis
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About CPI

Climate Policy Initiative (CPI) is a policy effectiveness analysis and advisory organization whose mission is to assess, diagnose, and support the efforts of key governments around the world to achieve low-carbon growth.

CPI is headquartered in San Francisco and has offices around the world, which are affiliated with distinguished research institutions. Offices include: CPI Beijing, affiliated with the School of Public Policy and Management at Tsinghua University; CPI Berlin, affiliated with the Department for Energy, Transportation, and the Environment at DIW Berlin; CPI Rio, affiliated with Pontifical Catholic University of Rio (PUC-Rio); and CPI Venice, affiliated with Fondazione Eni Enrico Mattei (FEEM). CPI is an independent, not-for-profit organization that receives long-term funding from George Soros.

Executive Summary

Renewable energy deployment in the United States is booming. Renewable electricity generation has more than doubled since 2005,[1] bringing reductions in air pollution and greenhouse gas emissions. The doubling was financed largely through private investment mobilized by state and federal incentives and other policies, leading to substantial expansion of the renewable energy industry.

While solar and wind costs have fallen, rising deployment has increased the cost to government of providing the incentives. Key federal policy incentives are now beginning to expire, just as federal lawmakers are looking for opportunities to reduce the deficit. It is therefore important and timely to review the performance of federal renewable energy incentives.

In this paper, we address three specific questions:

1. How important are federal incentives for encouraging renewable energy deployment?
2. How cost-effective are these incentives as currently structured?
3. How could they be improved?

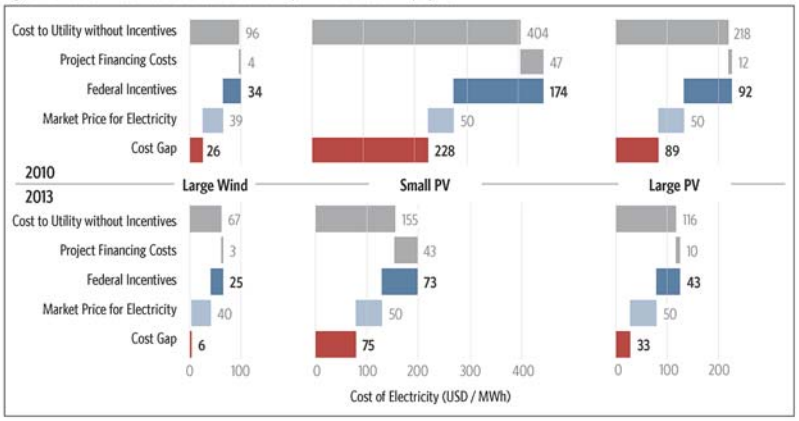
Incentive design influences how renewable energy projects are financed; project finance in turn affects the overall cost of electricity generation. Using detailed financial modeling, we have evaluated the impact of current federal incentives on the cost of three typical grid-connected utility-scale renewable energy projects—a large wind, a small solar photovoltaic (PV), and a large solar PV facility.

Under current law, a wind facility operating by the end of 2012 receives a production tax credit (PTC) of $22/MWh for electricity generated in its first 10 years while a solar PV facility operating by the end of 2016 receives an investment tax credit (ITC) equal to 30% of eligible project investment costs.

This analysis demonstrates how the federal government can modify these incentives to save money, while sustaining strong support for U.S. renewable energy deployment.

1 Net Generation by Energy Source: Total (All Sectors), June 27, 2012, Electric Power Monthly, Growth refers to non-hydro renewables.

Figure ES-1: Federal incentives are critical to the viability of wind and solar PV projects.

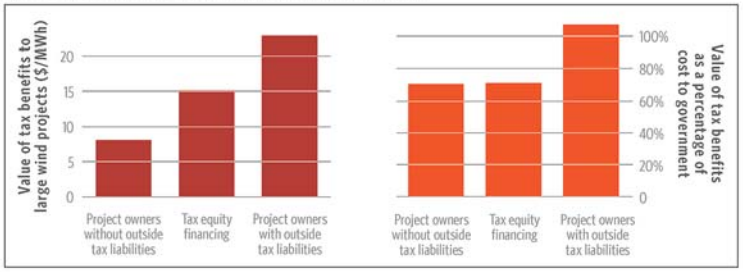


Key Findings

1. **Federal incentives have been critical to the viability of most renewable energy projects.**
   - The federal incentives available to projects financed in 2010[2] bridged roughly half the gap between the costs of renewable electricity generation and expected market prices for electricity.
   - To bridge the remaining gap, projects have largely been deployed in areas that meet one or more of the following requirements: complementary state policies apply, there are significantly higher than average wholesale electricity prices, or development of conventional electricity generation is constrained.
   - The recession and resulting state fiscal constraints mean that in the absence of federal incentives, it is unlikely that states and ratepayers alone would have filled the gap.
2. **Wind is now almost viable based on federal incentives alone. The gap for solar PV is narrowing.**
   - Recent cost reductions and performance improvements mean that if current federal incentives are sustained, a large wind project built in 2013 will be nearly cost-competitive.
   - Steep reductions in solar PV costs over the last two years mean solar PV projects will be more cost-competitive in 2013, but will still need some state or ratepayer support to be viable.
3. **Tax incentives leak money.**
   - A stand-alone large wind project has limited tax liabilities. As a result, project developers can only use tax benefits many years after they are received, and realize just one-third of their potential value (Figure ES-2).
   - Project developers therefore enter into financial arrangements with outside investors with tax liabilities—tax-equity financing—to use the tax incentives as they are received.
   - However, these arrangements are costly and only enable developers to realize two-thirds of the value of the incentive—an inefficient use of government money (Figure ES-2).
4. **Government can save money while providing the same support for projects by using taxable cash incentives rather than tax incentives.**
   - A 1603 Cash Grant half the size of the current investment tax credit could deliver the same benefit to a solar PV project in 2013 at half the cost to government (Figure ES-3).
   - Taxable cash incentives can be even more

2 These were the 30% 1603 Cash Grant, accelerated depreciation, and 50% bonus depreciation.

Figure ES-2: Tax incentives have less value to projects with limited tax liabilities.



cost-effective for governments than non-taxable cash incentives such as the 1603 Cash Grant.[3]

- If the wind production tax credit was delivered as a taxable cash incentive, it would almost halve the cost to government while delivering the same benefit to wind projects (Figure ES-3).

5. **But we must mindful of how different incentives impact the risks borne by government.**
   - Investment-based incentives shift some project performance risks to the government, as the government pays a fixed fraction of the project's cost regardless of project performance.
   - Production-based incentives reward performance equally across all projects, but carry greater price-setting risks. This is particularly acute when technology prices are hard to predict.

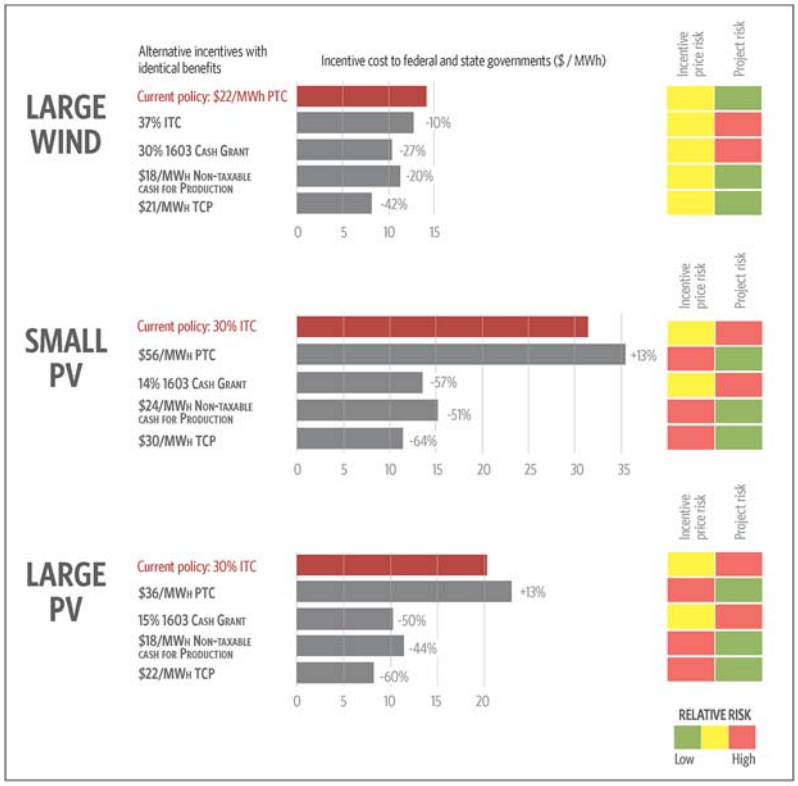
Policy Recommendations

Our work identifies two clear steps policymakers can take to improve the cost-effectiveness of federal renewable energy incentives:

1. **Extend the PTC as a taxable cash incentive for production (TCP) –** In the near term extend the $22/MWh PTC for wind, but deliver it as a $21/MWh TCP. This would:
   - Maintain the same effective level of support for wind projects.
   - Reduce the cost of the incentive to federal and state government by around 40% for every unit of clean electricity generated.
   - Avert a bust in the wind industry, and stimulate deployment even in states or regions with no local or state policy supports.
2. **Give solar PV projects the option to take a 20% 1603 Cash Grant in lieu of a 30% ITC –** This option could increase the value of the incentive to the project while reducing the cost to government of providing it.

3 Since the incentive is taxable, it results in additional project tax liabilities which can both help the project make better use of up-front tax benefits such as accelerated depreciation and increase tax revenues later in the life of the project to offset some of the cost of providing the incentive.

Figure ES-3: Policy alternatives and the costs and risks to federal and state governments.



Contents

1 Why Look at Federal Tax Incentives?

Renewable electricity generation in the U.S. has grown rapidly over the last decade. According to the U.S. Energy Information Association (EIA), wind and solar PV accounted for over 30% of new generating capacity added to the grid in 2010.

This growth has been enabled, at least in part, by policy drivers at the state (Renewable Portfolio Standards (RPS) and related incentives), national (federal tax incentives and stimulus funding), and international levels (European renewable energy incentives and Chinese manufacturing have driven economies of scale and cost reductions in wind and solar PV).[4]

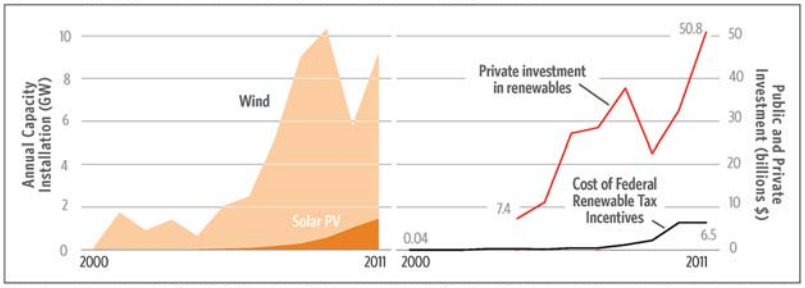
However, the continued growth of renewable energy deployment depends on overcoming a number of substantial policy, market, and budgetary challenges that are on the horizon.

4 This report is an expanded description of CPI analysis of federal renewable policies carried out to support collaborative work with the American Council on Renewable Energy (ACORE), the California Clean Energy Fund (CalCEF), and the Energy Foundation on the future of U.S. renewable energy policy.

Many federal incentives have expired or will do so shortly. Many key federal incentives require periodic re-authorization by Congress. Most were last extended as part of economic stimulus measures in late 2008 and early 2009 (the TARP and Recovery Act bills) and have recently, or will soon, expire. Table 1 summarizes the key incentives and their current status.

Extension of incentives is uncertain as rising deployment has brought rising incentive costs. Since federal incentives provide subsidies proportional to either investment in or production of renewable energy, their budgetary impact has risen with deployment. Large federal budget deficits, which arose as a result of the recession, have created substantial political pressure to reduce federal expenditures. Thus, the extension of these measures is now subject to substantially greater political risk. These risks have been exacerbated by the political fall-out from the failure of Solyndra (a solar manufacturer which was provided a Section 1705 direct loan). This has turned government support for renewable energy into a partisan political issue in an election year. On the other hand, substantial deployment over the last few years has leveraged significant direct private sector investment in projects and indirect investment down the supply chain and across the country, creating the potential for a countervailing political current.

Figure 1: Booming deployment and private investment has led to rising incentive costs to government



Sources: Annual grid connected solar PV and wind installations from EIA Annual Energy Outlook 2003-2012 including both the electric power sector and end-use generating capacity. Estimates of the budgetary impact of federal renewable electricity tax incentives (including the 1603 Cash Grant) are from CPI analysis based on OMB and JCT tax expenditure estimates. Estimate of new private investment in renewable energy projects leveraged in part by those incentives are from BNEF (2012) Global Trends in Renewable Investment 2012.

Table 1: Federal renewable energy incentives

Incentive	Origin	Expiration	Description	Risk to Government
Production Tax Credit (PTC) for Wind	Energy Policy Act of 1992	Placed in Service by **End of 2012**	$22/MWh tax credit for electricity generated	Incentive level may not be appropriate
Investment Tax Credit (ITC) for Solar	Energy Policy Act of 2005 (at 30%)	Placed in Service by **End of 2016**	Tax credit for 30% of eligible project costs	Project performance and cost risk
Investment Tax Credit (ITC) for Wind	Recovery Act of 2009	Placed in Service by **End of 2012**	Tax credit for 30% of eligible project costs in lieu of PTC	Project performance and cost risk
Section 1603 Cash Grant for Wind & Solar	Recovery Act of 2009	Start Construction by **End of 2011**	Option of a 30% cash grant in lieu of ITC or PTC	Project performance and cost risk
MACRS - Accelerated Depreciation	Economic Recovery Tax Act of 1981	-	5-Year depreciation for tax purposes	-
Bonus Depreciation	Economic Stimulus Act of 2008	100% by **End of 2011**, 50% by **End of 2012**	50% or 100% depreciation for tax purposes in first year	-
Section 1705 Loan Guarantee for Wind & Solar	Recovery Act of 2009	Closed Financing by **9/30/2011**	Government guarantee of up to 80% of project debt	Risk of project failure project performance and cost risk

State policy appears to be saturated. Contracts to meet state RPS requirements for the near future are already in place, leaving little room for additional growth. The U.S. Partnership for Renewable Energy Finance (US PREF, 2012) projects that RPS-driven demand can be met by deploying a little over 3 GW of new renewable electricity generation per year until 2030, significantly below recent annual deployment of around 10 GW per year.

Cheap natural gas and lower demand puts price pressure on renewable energy. The boom in domestic production of natural gas from shale formations has driven nominal gas prices down to levels last seen in the 1990s, transforming the outlook for the electricity sector. Gas generation now boasts lower marginal costs than coal generation in many states, and it delivers significant local air pollution reductions relative to coal.[5] Sustained lower electricity prices would diminish the economic viability of renewable technologies.

5 However, note that the long-term implications of shale gas are far from clear due to uncertain groundwater impacts, lifecycle CO_2 emissions, and long term production profiles.

Given these challenges, federal policymakers are looking to balance support for renewable energy with fiscal pressures. Improving the cost-effectiveness of federal renewable energy incentives could help.

In this work, we use project financial modeling and data on renewable energy project costs and performance to assess three aspects of the performance of current federal renewable energy incentives:

1. How important are federal incentives for encouraging renewable energy deployment?
2. How cost-effective are these incentives as currently structured?
3. How could they be improved?

For the first question, we provide an estimate of the impact of federal incentives—the extent to which federal incentives help bring the cost of electricity from solar and wind projects down towards market prices for electricity. We address the second question by comparing the cost to federal and state governments of providing the same level of benefit to a project using various currently employed incentives. Finally, we use insights gained from the first two analyses to propose an alternative incentive mechanism for wind—a Taxable Cash for Production (TCP) incentive—which can provide the same benefits as the current production tax credit (PTC), but at lower cost to federal and state governments.

In the next section, we discuss prior work on these topics. In section three, we provide an overview of the project data and financial modeling techniques used to address these questions, and discuss the strengths and weaknesses of our approach. In section four, we address the impact of federal incentives on the economic viability of renewable energy projects. In the fifth section, we discuss results regarding the relative cost-effectiveness of these incentives and a proposal for how the incentives might be modified to improve their cost-effectiveness. We conclude with recommendations to policymakers regarding near-term modifications to federal incentives which can improve their cost-effectiveness.

2 Prior Work on the Impact and Cost-Effectiveness of Federal Incentives

Our analysis builds upon a number of recent studies focused on the impact and cost-effectiveness of federal incentives. In this section we highlight some key findings from these studies in two important areas for our work—the nature and impact of the various financial structures used by renewable energy projects to monetize tax incentives, and the relative cost of various federal incentives.

2.1 Impact of Financial Structures

The Electricity Markets and Policy Group at Lawrence Berkeley National Labs (LBNL) have studied the financing structures used by the wind industry to utilize federal tax incentives since the mid-1990s. The key results from this work and related efforts relevant to this work are:

> The details of the financing arrangements made by a project developer to utilize tax incentives—tax equity financing—can impact the cost of electricity by as much as 30%.

The choice of tax equity financing structure can impact electricity costs by as much as 30% - Harper et al. (2007) and Bolinger et al. (2010) outlined in detail the rationale, structures, and terms for tax equity financing—the arrangements used by wind project developers without tax liabilities outside of the project to monetize tax incentives. They estimated that the variation in cost of electricity due to the choice of financing structure using the same tax incentive could be as high as 30%. This work significantly informed and motivated our focus on detailed modeling of tax equity financing structures.

The variation is tied to inefficiencies in tax equity capital markets - The choice of structure is often constrained by the specific risk and tax appetites of project stakeholders. In particular, the complexity of tax equity financing and the relatively small number of tax equity investors with significant, predictable, long-term tax liabilities and the capacity to structure these deals has resulted in a relatively thin market.

Recent evidence suggests that tax equity market conditions are improving - Some of these constraints should loosen as capital markets for renewable energy projects grow and become more efficient. More recent publications focused on current state of play in wind project financing—for example, Mintz Levin (2012) and Chadbourne & Parke (2012)—suggest that the pool of tax equity investors has widened (to over 20) and that recent transactions have largely utilized the more efficient structures such as institutional investor flips. As a result, we focus our work on some variants of the more efficient structures described in these reports.

2.2 Relative Cost-Effectiveness of Federal Incentives

The American Recovery and Reinvestment Act gave wind developers a choice between the ITC, PTC, and 1603 Cash Grant for projects which began construction by the end of 2010. This motivated a number of groups to study the relative cost-effectiveness of these federal incentives. Key conclusions from these studies relevant to our work are:

> Cost and performance dictates the choice between the PTC and the 1603 Cash Grant for any given wind project. However, overall, the 1603 Cash Grant has spurred greater deployment, reduced financial transaction costs, and halved the unit cost to government relative to the PTC.

Project cost and performance dictate the choice between the PTC and 1603 Cash Grant – Bolinger et al. (2009) found that the relative value of the PTC and the 1603 Cash Grant varied with costs and capacity factors across wind facilities. Lower cost, higher capacity factor facilities were likely to get more value from a PTC than the 1603 Cash Grant. This was confirmed by Bolinger et al. (2010) who noted that a quarter of all large wind projects in 2009 and early 2010 chose the PTC over the cash grant in spite of the poor tax equity market conditions.

The 1603 Cash Grant resulted in additional deployment relative to the PTC it replaced – Bolinger et al. (2010) also assessed the extent to which the choice of a 1603 Cash Grant enabled additional deployment relative to the

PTC alone. To assess if the project could have been built under a PTC, they analyzed the finances of wind projects deployed using the 1603 Cash Grant and found that roughly 2.4 GW out of the nearly 10 GW of wind projects built in 2009 would not have gone forward under a PTC.

High transaction costs for tax equity – The U.S. Partnership for Renewable Energy Finance's (US PREF) 2011 report on tax equity and tax credits estimated the difference in transaction costs between financing a solar project using the ITC and tax equity relative to a 1603 Cash Grant and debt financing. Their results are used as financial inputs to our models (see Table A.2 in Appendix A). Further, they noted that tax equity structures are difficult to leverage. This is because many tax equity investors are institutional investors with constrained risk profiles, so they are often loath to allow their tax equity investment to be subordinated to project-level senior-term debt.

The 1603 Cash Grant can cut government costs per MWh in half relative to the PTC – The Bipartisan Policy Center's (BPC) 2011 report cited analysis by Bloomberg New Energy Finance (BNEF) in 2010 that found the 1603 Cash Grant could have provided the same benefit to investors as a PTC for roughly half the total budgetary cost for projects deployed between 2004 and 2008.

The 1603 Cash Grant had much higher overall costs to government than initial expectations – The Majority Staff of the House Committee on Energy and Commerce, Subcommittee on Oversight and Investigations released a report assessing the impact of the 1603 Cash Grant. They note that the program is costing the government much more than initially anticipated. From the work of Bolinger et al., this appears to be the result of the 1603 Cash Grant leading to additional deployment relative to the PTC.

The ITC pays for itself and provides the government with a 10% return – US PREF (2012) teamed up with SolarCity and performed a tax analysis of a residential solar system and found that over the life of the project, the tax revenue from electricity sales significantly exceeds the cost to government of providing the ITC, in fact providing a 10% annual return above the amount provided.

Feed-in-Tariffs are more cost-effective than tax incentives – BNEF (2011) examined the relative cost-effectiveness of various types of incentives used globally. In particular, they compared the impact of a feed-in-tariff and a production tax incentive of the same level on the cost of electricity of a wind project. They found that feed-in-tariffs could deliver greater reductions to the cost of electricity for the same level of incentive.

We will discuss the implications of our work on these claims in the concluding section of this report.

3 How are We Assessing Federal Policy Impact and Cost-Effectiveness?

We use project financial modeling to evaluate the impact of current federal incentives on the cost of electricity generated by three typical utility-scale renewable energy projects—a large wind, a small solar PV, and a large solar PV facility. We focused on utility-scale projects because they represent the bulk of renewable energy generation. These three cases represent the majority of currently installed capacity (large wind), the majority of installed projects (small solar PV) and account for the largest share of recent deployment growth (large solar PV). Assumptions are based on the actual costs, financing, and operation of renewable energy projects financed over the last few years.

In this section, we begin by describing the project data that we analyzed, the model used for the analysis, and the outputs of the model relevant to addressing federal policy impact. We end the section with a discussion of some key strengths and limitations of using project financial modeling to address federal renewable energy policy impact and cost-effectiveness.

3.1 Getting Cases from Actual Project Statistics

To address the impact and cost-effectiveness of federal incentives, we began by collecting data on the timing, cost, performance, and financing structures and conditions of utility-scale renewable energy projects which were either financed or deployed in the U.S. between 2008 and mid-2012. The data is summarized in greater detail in Appendix A, but the key project data needed to faithfully capture the cost of electricity and the most important sources used to obtain them were:

- **Project costs and timelines** – We used cost and timelines from Bloomberg New Energy Finance's proprietary database of projects either financed or deployed from 2009-12.
- **Project performance** – We used the historical performance of most large renewable generators from the Energy Information Administration's project database operating from 2008-11, along with electricity market and time of use data from various sources.
- **Financial structures** – We used published ranges of expected after-tax returns to investors, debt conditions, and examples of financial structures and requirements from a number of sources (LBNL, US PREF, Mintz-Levin, S&P, Moody's).

We used the distribution of project sizes to identify clusters of projects which could be reasonably modeled by single representative cases. Based on the size and total generating capacity of those clusters, we chose three of particular importance. We used the median values for key technical characteristics of each of those three clusters to define generic project cases—a large wind farm, a small utility-scale solar PV facility, and a large solar PV facility. All cases were assumed to have been financed in mid-2010 for our policy impact analysis, roughly the mid-point of the range of project financing dates we studied.

Table 2 summarizes the basic characteristics of the three 2010 cases.

Looking forward to potential policy impacts and cost-effectiveness in 2013, we use modified assumptions based upon recent market conditions (Table 3).[6] The key changes relative to 2010 are: updated costs for wind and solar PV; improved performance for wind; increased size for large PV; slightly lower tax equity costs for solar PV; and revised policy settings (ITC for solar, and we assume the PTC for wind is extended to 2013).[7]

6 Key sources are US PREF (2012), Wiser et al. (2012) and Chadbourne & Parke (2012).

7 Our assumptions for cost and performance are based on work by LBNL and NREL on recent trends in wind turbine costs - http://eetd.lbl.gov/ea/ems/

Table 2: Basic details of the three representative 2010 cases

CASE	SIZE (MW)	CAPACITY FACTOR (%)	COST ($/W)	RATIONALE
Small Solar PV	1.2	18	6.0	Majority of deployed projects
Large Solar PV	15	24	4.2	Greatest deployment growth
Large Wind	131.5	31	2.1	Majority of deployed capacity

Table 3: Basic details of the three 2013 cases

CASE	SIZE (MW)	CAPACITY FACTOR (%)	COST ($/W)
Small Solar PV	1.2	18	2.2
Large Solar PV	60	24	2.2
Large Wind	131.5	39	1.8

Full technical and financial inputs for all 2010 and 2013 cases are provided in Appendix A.

3.2 From Case Data to Impact and Cost-Effectiveness

We developed a levelized cost of electricity (LCOE) calculator and financial model to take the available technical and financial characteristics of a case in a given policy scenario and calculate:[8]

1. The impact of federal incentives and financing costs on the cost of electricity to ratepayers
2. The total cost to state and federal government to achieve a given cost of electricity to ratepayers

Here, we will describe the methods used to arrive at the two metrics and discuss the interpretation of the results.

3.2.1 Determine the financing structure used for each case and policy scenario

For each case and policy scenario, we first used the LCOE calculator to determine the lowest cost of electricity that could be achieved while meeting all financing requirements. Specifically, we:

- **Determined possible financial structures** – We used published data and studies to manually define a list of potential financing structure scenarios (e.g. with or without debt, tax equity, construction financing), each accompanied by specific required investor returns. We relied heavily on the recent work of Mark Bolinger and collaborators at LBNL and NREL regarding the specific tax equity structures used (see, for example - http://eetd.lbl.gov/ea/ems/reports/lbnl-2909e.pdf).[9]
- **Calculated the cost of electricity for each financial structure** - For each financing structure, we used the LCOE calculator to compute the additional revenue above market prices needed to simultaneously:
  - **Maximize debt volume** – This is determined by the requirement that the cash flow available to pay debt in each period exceeds the required payment by a certain Debt Service Coverage Ratio (DSCR).
  - **Meet all investor return requirements** – This is determined by the requirement that the cash flows for each equity or tax equity investor reach their required internal rate of return (IRR) at the appropriate time while optimizing the tax equity financing arrangement (within the constraints of IRS rules) to minimize the cost of electricity.[10] The financial model of the project is used to verify that the additional revenue for each financing structure does indeed allow the project to meet the relevant IRR and DSCR requirements.
- **Picked the financial structure with lowest final cost of electricity** – We manually selected the financial structure that resulted in the lowest final cost of electricity, and modeled the cash and tax flows assuming the use of that structure for further calculations.

3.2.2 Calculate the impact of federal incentives on the cost of electricity

We used the model of the cash and tax flows of the lowest cost structure to assess the impact of federal provisions on the cost of electricity in each case and policy scenario. Specifically, we:

- **Calculated a counterfactual cost of electricity without incentives** – We used the cash flow model to calculate levelized cost of electricity for each project, assuming that it was financed by a regulated utility as an investment on its balance sheet without any incentives—that is, using a discount rate equal to the utility cost of capital.[11]

reports/wind-energy-costs-2-2012.pdf. Specifically, we use the average of the projected 2013 capacity factors and costs of all technology options expected to be available for a wind regime corresponding to our 2010 large wind case (roughly 6.5 m/s - see Table A-2).

8 The cash flow model is based on a financial model previously developed by CPI: see Appendix A.1 of http://climatepolicyinitiative.org/publication/the-impacts-of-policy-on-the-financing-of-renewable-projects-a-case-study-analysis/. The additional capabilities of the LCOE calculator and cash-flow model used to perform this calculation are described in Appendix B.

9 We do not include leveraged tax equity structures in this analysis as very few projects have employed these structures to date, due to concerns with subordination of tax equity structures to project-level debt (see discussion in US PREF (2011)).

10 We do not, however, model capital adequacy requirements.

11 The regulated utility cost of capital is often used as a benchmark for appropriate capital costs for generation assets, due to the prevalence of rate of return regulation. In this case, we used the cost of capital calculated by the California

We believe that this provides a realistic baseline cost of electricity without policy support.

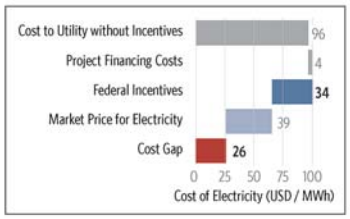
- **Compared the counterfactual and the actual cases to capture the impact of incentives** - We then calculated the contribution of incentive and financing cash and tax flows to the difference in levelized cost between the utility financed counterfactual case and the actual financing.

For example, consider the large wind case in 2010 assuming the use of a 1603 Cash Grant and debt. Figure 2 summarizes the results of our analysis where the terms are defined as follows:

- **Cost to utility without incentives** – The cost of electricity ($96/MWh for wind) in the absence of federal incentives, assuming on-balance sheet financing by a utility with roughly 8% weighted average cost of capital in the middle of 2010.
- **Project financing costs** – The costs or savings associated with using project-level equity and debt financing as compared to balance sheet financing by a utility. This includes the relative cost of capital (for wind, a $5/MWh saving), financing fees ($1/MWh cost for wind), and costs associated with carrying tax benefits forward ($9/MWh cost for wind).
- **Federal incentives** – The reduction in the cost of electricity due to federal incentives (roughly 34% of total costs for wind, including $24/MWh from the 1603 Cash Grant and $11/MWh from accelerated depreciation and 50% bonus depreciation).

Public Utilities Commission for the 2009 Market Price Referent, 8.25%.

Figure 2: The impact of federal incentives on the large wind case in 2010 with a 1603 Cash Grant



- **Market price for electricity** – The expected after-tax revenue from electricity sales at projected future national average wholesale market prices (taken from EIA's 2010 Annual Energy Outlook) adjusted for the time of use (about $39/MWh for wind).
- **Cost gap** – The difference between the final cost of electricity and expected market prices for the electricity generated ($26/MWh for wind). This gap must be covered by additional project revenues from ratepayer or state/local government funds.

Note that the final cost of electricity—the after-tax revenue needed per MWh of electricity generated to meet investor return requirements after federal incentives—is the sum of the market price for electricity and the cost gap ($65/MWh for wind).

3.2.3 Calculate the cost of the federal incentive to all levels of government

We then calculated the cost to all levels of government (either in the form of direct payments or foregone tax revenues) of policy supports utilized by the project (such as grants, tax credits, accelerated depreciation, or deductions of interest expenses). This cost was calculated as the present value of all flows to government discounted using zero-coupon treasury security yields of the appropriate maturity.[12] That is, we are assuming that any impact on government cash flows is marginal and therefore must be financed through a government debt transaction (either the purchase or sale of a treasury security). Note that since we are computing costs to all levels of government, this is implicitly assuming that marginal shifts in state government finances are enabled by transfers from the federal government.[13]

The cost to government of an incentive isn't just captured by the direct cash flows associated with, for example,

12 These are bills, notes, or bonds depending on the maturity—we refer to them just as treasuries.

13 The focus on combined cost to all levels of government arises from a modeling limitation—our model currently uses a blended state and federal tax rate for calculations. Another consequence of this is that we cannot separately distinguish state and federal tax benefit carry-forward. This could, therefore, underestimate the cost to government of carrying forward federal tax credits (but not deductions). However, as all the financial structures we consider in policy scenarios with tax credits involve the use of tax equity, this issue does not affect our current analysis.

foregone tax revenues due to the tax incentive. The choice of incentive may affect the extent to which the project utilizes other federal tax provisions—such as accelerated depreciation or business interest deduction tax benefits. For example:

- The use of an investment tax credit reduces the depreciable basis of the facility by 50% of the value of the investment tax credit, thereby reducing the cost to government of the accelerated depreciation benefit.
- A production-based cash incentive in lieu of a PTC provides additional project cash flow that may allow the project to take on a larger loan than it would have without the incentive. As the interest on the larger loan is tax deductible, this increases the cost to government of the interest deduction.

However, accelerated depreciation and interest deduction tax benefits are broadly provided across industries in order to correct for the distortion of economic activity associated with corporate income taxation.[14] Further, when a legislative proposal for an incentive is scored (that is, assigned a cost either by the Congressional Budget Office or the White House Office of Management and Budget) interactions of this form are not included, as those broader investment tax provisions are treated at a macroeconomic level and scored using relations to expectations of investment growth. So, we separately report the **incentive cost**—the cost to state and federal government that results directly from the incentive alone and is relevant to scoring—and the change to the cost of accelerated depreciation and interest deduction tax expenditures resulting from the interaction. The sum of these two costs is the **total cost** to state and local governments of providing the incentive at a project level.

Take, for example, the large wind case. We calculate the cost of a 1603 Cash Grant to state and federal government by calculating cash flows to and from government associated with the provision of the cash grant alone, discounted at treasury rates. This yields an incentive cost of $18 / MWh. The loss in tax revenues associated with accelerated depreciation is $5 / MWh, and the loss in tax revenues associated with the provision that enables businesses to deduct interest payments on debt as expenses for tax purposes is $5 / MWh. This comes to a total cost to federal and state government of $28 / MWh.

14 See, for example Zee et al. (2002)

Even more broadly, you could consider how sales of power from the project impact tax revenue (e.g., see US PREF, 2012 undertaken in collaboration with SolarCity on the tax revenue impact of the ITC). However, such revenues are part of the base tax code; if the incentive had not redirected investment and consumption to the renewable energy facility, greater investment and consumption would likely have occurred elsewhere, with associated tax revenue. So, we exclude those tax collections from our analysis.[15]

3.3 Limitations and Opportunities

Project-level analysis like this can provide precise answers to questions regarding the costs and benefits of policies at a micro-level. However, it can leave out many critical costs or benefits which are often only visible when looking across project portfolios, at the broader economy, or over longer time periods. For example, this analysis doesn't capture policy impacts on innovation and technology costs. The analysis also does not address in detail how the impact and cost-effectiveness of federal policies may vary across the country due to the interaction of federal policies with the multitude of different state policies (such as Renewable Portfolio Standards). System-wide issues which can be affected by the nature of the incentive provided, such as grid reliability and stability, are also beyond the scope of this analysis.

We do not address macro-economic impacts of polices—on energy markets, prices, demand, and on the supply and cost of capital. So we cannot estimate the overall magnitude of the impact of policies on likely deployment rates, and therefore only provide estimates for the impact of policies per unit of electricity generated. However, our analysis of cost-effectiveness only compares policy scenarios which deliver the same benefits to the project as current policies. Therefore, we can (and do) reasonably assume that the scenarios would result in similar levels of deployment.

In spite of these limitations, careful accounting of costs and benefits at the project level can help evaluate policy impact and cost-effectiveness. This careful accounting captures the direct financial impacts of the incentives,

15 We note that this argument fails if such counterfactual private activity is significantly less likely—for example, in the case of a depressed economy, where fiscal policy may stimulate truly additional economic activity. However, in that case, the more appropriate question may be if the incentive has a higher economic multiplier than other forms of fiscal spending.

provides a reasonable first approximation to understanding their impacts, and can deliver insights robust and simple enough to help build consensus for policy change.

4 Importance of Federal Incentives

Absent incentives, the cost of electricity from wind and solar PV still exceeds current market prices in much of the U.S. Policy supports are employed to bridge the gap between the cost of renewable electricity and the price at which that electricity can be sold on wholesale electricity markets. These supports are provided for a number of reasons – for example, to correct for the fact that some of the benefits of renewable energy generation, such as avoided carbon emissions, are not yet reflected in market prices. These supports can also come from a number of sources: ratepayers (through requirements imposed by state or federal regulators), state and local governments, or federal incentives. To explore the relative importance of federal incentives, for each of the three project types, we:

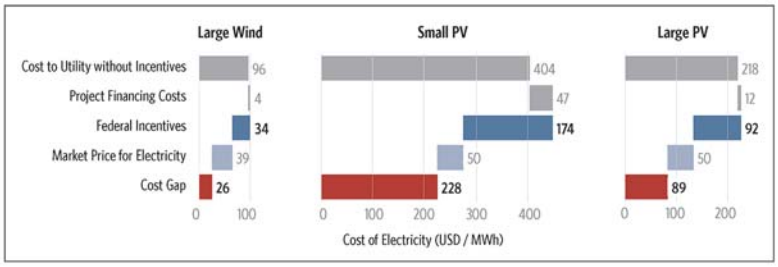
- Modeled the most widely used incentive and financial structures for projects financed in mid-2010 and those expected in 2013 assuming extension of current policy,
- Computed the impact of the incentive on the cost of electricity, and
- Compared it to the remaining gap to wholesale market prices.

4.1 Federal Incentives and Project Viability in 2010

Federal incentives available to projects financed in 2010—specifically the 1603 Cash Grant and accelerated depreciation—bridged roughly half the gap between the costs of renewable electricity generation and expected market prices for electricity.

Project finance structures with project level debt and sponsor equity had the lowest cost for all cases. While project costs varied across technologies and sizes, federal incentives were not enough to bridge the gap between electricity generation costs and market prices for electricity for the vast majority of projects financed in 2010. Therefore, deployment of wind and solar has proceeded largely in areas where complementary state, local, or ratepayer policies apply (e.g. an RPS requirement), in regions with significantly higher than average wholesale electricity prices, and/or in places where conventional electricity generation development is constrained.

Figure 3: Impact of federal incentives on projects financed in 2010



4.2 Were Federal Incentives Necessary?

In theory, states or ratepayers could have increased their support to bridge the cost gap in the absence of federal support. In practice, the global recession and the resulting state fiscal constraints made such additional support unlikely.

Over the last decade, a number of states have implemented renewable energy policies such as binding targets for renewable energy generation or state tax concessions. These policies often include mechanisms to cover the gap between the cost of renewable electricity generation and market prices for electricity. These may involve explicit funding or subsidies such as tax concessions, rebates, or separate state funds for renewable energy. Others may involve implicit support—for example, regulators may be empowered to authorize increases in retail electricity prices to cover a utility's incremental costs for compliance with renewable energy targets.

In theory, states with such policies in place could have covered the cost gap in the absence of federal support through the increased use of such mechanisms. However:

- **State budget constraints from the recession made increasing support from states unlikely.** The global economic downturn, which began with the financial crisis of 2008, was particularly difficult on state budgets. Significant tax revenue losses associated with economic contraction along with increased mandatory spending to provide services to those impacted by the downturn (such as through Medicaid insurance) created significant fiscal pressures in nearly every state.[16] While the American Reinvestment and Recovery Act provided $145 billion to state and local governments to help them cope with the downturn, this covered only about 40% of state deficits and states were nevertheless forced to make severe cuts to essential services. The cuts were particularly severe in states with balanced budget requirements. These constraints made it unlikely that states would have increased spending if federal renewable energy incentives had been removed.
- **The recession's impact on electricity demand made additional ratepayer support unlikely.** The impact of the recession on ratepayers was similarly stark. Unemployment reached nearly 10%. According to FERC, electricity demand in the U.S. fell by 4.2% in 2009 due to decreased economic activity (the steepest drop in 60 years). As a result, utilities and the relevant regulators would have faced an exceptionally difficult business and political environment for making a case to increase retail rates to cover additional costs of new renewable electricity generation.
- **European states facing fiscal constraints pulled back renewable energy policies but U.S. states did not.** Nevertheless, renewable energy deployment in the U.S. continued to grow during the recession, and most state renewable energy targets prior to the recession were either maintained or strengthened. This is in marked contrast, for example, to the impact of the downturn on renewable energy deployment in Europe. E.U. Member States facing significant fiscal constraints—such as Spain and Italy—abruptly curtailed their renewable energy policy ambitions in the absence of E.U.-wide fiscal support analogous to the support provided by federal incentives to U.S. states.

Thus, we believe that additional state or ratepayer support was not likely and that federal policies were critical to the recent growth in renewable energy deployment. Due to the continued weakness of the global economy, it does not appear that the budget and demand constraints noted above are likely to ease in the near term. Further, as we noted in the introduction, current state policies alone do not appear to be strong enough to sustain the level of growth in renewable energy deployment seen over the last four years. The PTC was allowed to expire at the end of 2001 and 2003 when wind faced similar market conditions, leading to booms just prior to expiration followed by substantially lower deployment in the year after. As a result, it is likely that the expiration of federal incentives, in particular, the PTC for wind, could lead to significantly reduced levels of annual renewable energy deployment in the near future, another boom and bust cycle for renewables.

16 See for example - http://www.brookings.edu/research/reports/2011/10/27-state-budgets-gordon

4.3 Federal Incentives and Project Viability in 2013

Rapid reductions in generation costs for both solar PV and wind over the past two years have substantially narrowed the cost gap. If these trends continue and the PTC is sustained, wind could be almost viable in 2013 based on federal incentives alone, leading to wind deployment in states without other support policies.

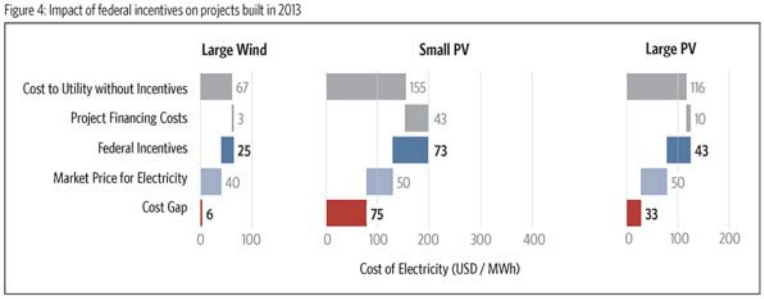
Unlevered tax equity financing leads to the lowest cost of electricity for all three cases in 2013.

Turbine performance improvements and lower turbine contract prices mean the unsubsidized cost of wind electricity coming on-line could drop by nearly 30% from $96 in 2010 to $67/MWh in 2013. If the PTC were extended through 2013, federal incentives alone (the PTC and accelerated depreciation, with tax equity financing at current costs) could cover nearly the entire gap for an average wind project, leading to a final cost of electricity of $46/MWh, within $6 of expected average market prices for the electricity generated. At these prices, wind could be viable in some regions without complementary state policies. As existing state policies can only drive limited growth, this could encourage significant additional deployment and avert a significant contraction of the renewable energy industry.

Solar PV has seen even steeper cost reductions but still requires some support beyond federal incentives. Nevertheless, the cost gap is closing. If U.S. utility-scale installations in 2013 can match Germany's average installed costs for small ground-mounted solar PV installations in mid-2012 (about $2.20/W—a conservative assumption, given smaller installations are generally more expensive than larger ones) large solar PV would face a market price gap after federal subsidies of about $33/MWh, about a third of the gap seen in 2010. This suggests that solar PV could soon be cost-competitive in states with particularly good solar resources, higher than average electricity prices, or even modest complementary policies.

Despite these gains, a number of challenges could significantly diminish the competitiveness of renewable technologies in the near term. These include a significant fall in expected electricity prices due to falling natural gas prices and softer economic growth, the risk of curtailment, and international renewable technology trade disputes.

Figure 4: Impact of federal incentives on projects built in 2013



5 Cost-Effectiveness of Federal Incentives

The form of the incentive provided can significantly impact the cost of financing a project. This issue is particularly acute with tax incentives:

> Cash incentives are a more cost-effective way to support projects than tax incentives.

Project stakeholders must have significant, predictable tax liabilities to make use of federal tax incentives. In principle, this promotes renewable energy business models which are more profitable and more likely to be sustainable. Unfortunately, project owners do not typically have sufficient tax liabilities—whether from the project itself or other business activities—to use the tax benefits as they are generated.

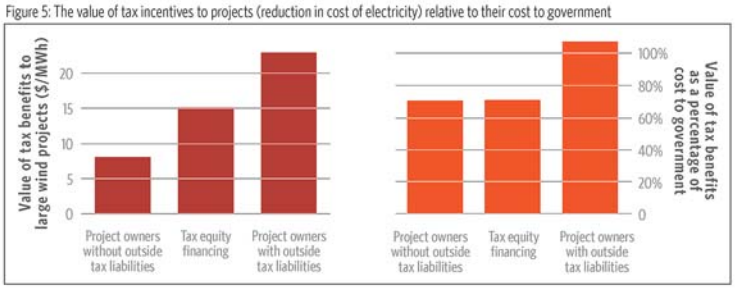
For a large wind project with debt in 2010, the PTC and accelerated depreciation benefits reduce the cost of electricity by $24/MWh (at a cost to governments of $21/MWh) if the investor has enough tax liabilities from other business activities to use all the tax benefits as they are generated by the project. However, the value of these incentives is just $8/MWh (at a cost to governments of $11/MWh) if the investor does not have tax liabilities from other business activities. So, without outside tax liabilities, the tax benefits have only a third of their potential value to the project.

This motivates project developers to bring in an outside investor with such tax liabilities—a tax equity investor—to monetize the tax incentive and finance the project. However, the high cost of tax equity financing only allows project developers to realize two-thirds of the full value of the tax benefits ($15/MWh, at a cost to governments of $21/MWh). Thus, the costs associated with tax equity finance substantially reduce the impact and cost-effectiveness of the incentive.

To quantify how these issues impact the relative cost-effectiveness of current federal policies, we:

- **Calculated the cost of electricity for each 2013 case assuming current policy, the use of project-level debt, and project owners without outside tax liabilities.** Assuming current policy (ITC for solar PV, PTC for wind), we calculated the cost of electricity in the lowest-cost project finance structure. We assumed that project owners and investors did not have any tax liabilities from other businesses they expected to use to offset the tax benefits generated by the project.
- **Determined the level of alternative incentives which achieve the same cost of electricity.** For each alternative policy (a 1603 Cash Grant, PTC, ITC, non-taxable cash incentive for production, or a taxable cash incentive for production) we used the levelized cost of electricity (LCOE) calculator

Figure 5: The value of tax incentives to projects (reduction in cost of electricity) relative to their cost to government



to determine the level of incentive required to achieve the same cost of electricity. This is not consistent with current policy, as the ITC is fixed at 10% or 30% of project costs, while the PTC is fixed at either $11/MWh or $22/MWh—however, it is necessary to make a meaningful comparison of their relative cost-effectiveness. We choose the project finance structure which leads to the lowest level of incentive for each policy scenario (unlevered tax equity for the ITC and PTC; debt and equity for the other three), again, assuming that project owners do not have outside tax liabilities.

- **Calculated the cost to the state and federal government.** We then determined the total cost to state and federal government for providing the incentive for each case and policy scenario.

5.1 Small Solar PV in 2013 and 1603 Cash Grant

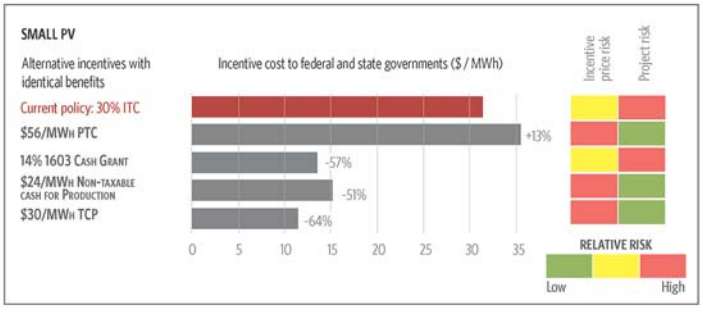
> For small solar PV in 2013, a 14% 1603 Cash Grant could provide the same benefit to the project as the current ITC at half the cost to state and federal governments.

The current 30% investment tax credit (ITC) for an average small PV project in 2013 would cost federal and state governments $31/MWh. A 14% 1603 Cash Grant would provide the same benefit to the project and its investors for a 57% lower cost to government. It would take a $56/MWh production tax credit (PTC) to get the same benefit; this would cost governments 13% more than the ITC. Thus, the federal government could provide greater benefits to small solar PV projects at lower unit cost by offering a 1603 Cash Grant for between 14 and 30% of eligible project costs, in lieu of the ITC (Figure 6). As shown in Figure 9 below, the same would be true for large solar PV.

The differences in cost to government reflect the impact of differing levels of risks associated with the timing and nature of the benefits delivered to project stakeholders:

- **The timing of the incentive** – Up-front investment incentives reduce the overall need for and cost of financing. Thus they deliver greater benefits to the project for every dollar of government spending.
- **The ability of investors to use the tax benefits** – Cash incentives can be used by any investor, whereas tax benefits require tax liabilities. Tax equity investors take the risk that they may not have enough tax liabilities to use the tax credits, so they demand a higher return. This accounts for the difference between the cost to government of the ITC and the 1603 Cash Grant. The PTC is further impacted by the timing and variability

Figure 6: Small PV policy options – costs and risks to federal and state governments



of the tax benefits, which are tied to the level of annual production from the facilities. Investors need to be sure that they have tax liabilities every year over ten years with enough of a cushion to account for varying levels of annual production to make full use of PTC benefits.

While the ITC and the 1603 Cash Grant are less expensive than the PTC for the average project, they allocate some project cost risks to the government.

The PTC fixes the cost to the federal government for every MWh of renewable electricity produced. In contrast, investment-based incentives (ITC or 1603 Cash Grant) provide the same subsidy for any given investment independent of the quality of the renewable resource or the performance of the project: This leads to variable rewards per MWh. Our analysis suggests that this variation is significant across existing solar PV power plants; comparable investment-based incentives translate to a nearly 70% variation in the per MWh cost of the subsidy to government.

Investment-based support enables government to share the burden of technology cost risks with investors. This makes sense for the scale-up of innovative technologies. However, it is less justified for mature technologies such as wind and solar PV, where developers and investors can manage cost risks through market measures such as contractor cost guarantees and competitive sourcing. Further, as investment-based support allows investors to realize targeted returns very early, it provides a weaker incentive to invest in the best resource or maintain or improve ongoing production. While it is too early to conclusively judge the effect on U.S. solar PV development, we can see some hints of this weakness in the variation in capacity factors observed in EIA solar PV power plant operations data.

The 1603 Cash Grant is particularly valuable for smaller projects where the fixed transaction costs of tax equity financing can exceed the value of those benefits.

Cash incentives for production could reduce costs to government and, at the same time, allocate project cost risks to developers and investors (Figure 6). However, these increase the incentive price risk to government, as discussed in section 5.3 below.

For the small solar PV facilities, a 1603 Cash Grant led to a cost of electricity at least $15/MWh lower than any financing structure with a tax credit. This is largely due to the fixed financial fees associated with obtaining tax equity financing for small projects, equivalent to $29-38/MWh generated. On the other hand, the large solar PV case yielded essentially equivalent cost of electricity with the ITC and 1603 Cash Grant (see Figure 9 and the subsequent discussion).

5.2 Large Wind in 2013 and a Taxable Cash Incentive for Production (TCP)

A $21/MWh TCP in lieu of the $22/MWh PTC could provide the same support to wind projects at about half the cost federal and state governments, without shifting project risks to government.

As we saw in the last section, a good federal incentive for renewable energy:

1. Delivers benefits efficiently to the investor by minimizing timing and liquidity risks, and
2. Allocates project risks to the parties best able to manage the risks (i.e., for emerging technologies, risks are shared between the private sector and government; for mature technologies, risks are managed by the private sector).

Unfortunately, none of the current federal incentives can do both of these things, at least for wind. Here, we explore a new option—a taxable cash incentive for production (TCP)—which could fulfill both these requirements. Under a TCP, the federal government would provide projects with periodic cash payments based upon actual renewable production. These cash payments would be treated as taxable income.

Replacing the $22/MWh PTC for a wind project in 2013 with a TCP of $21/MWh can provide the same benefits

to the project (the same cost of electricity while meeting all financing requirements) but at just above half the cost to state and federal government. It provides many of the benefits of the 1603 Cash Grant, without shifting project risks which can be better managed by the private sector to the government (Figure 7).

As we noted in the last section, extension of the PTC could see accelerated deployment as wind becomes viable in some states without complementary policies. A move to a TCP could substantially reduce the associated impact on federal budgets or enable a longer-term extension at similar total cost.

The TCP incentive is essentially equivalent to a Feed-in-Premium (FiP), but is paid directly by the federal government rather than through ratepayer funds. The greater cost-effectiveness of a Feed-in-Premium relative to tax incentives was noted in BNEF (2011), and is consistent with our results. Hudson Clean Energy Partners proposed a similar—but not taxable—cash production incentive in 2009 (see BPC (2011)). The non-taxable cash production incentive is less expensive than the PTC because it eliminates the risks and costs associated with monetizing tax benefits. The taxable cash incentive saves even more for the following reasons:

- **Greater cash available for debt service enables higher leverage, reducing financing costs** - While an up-front subsidy can reduce the requirement for expensive tax equity, the additional cash flow available for debt-service provided by a TCP can support greater project-level debt. As debt is generally significantly less expensive than equity, this reduces financing costs.
- **Greater debt increases interest tax benefits** - As the interest on debt is tax deductible, the TCP allows developers to take advantage of this existing tax benefit.
- **Greater taxable revenue monetizes accelerated depreciation benefits** - Further, as the cash incentive is taxable, it provides the project with additional tax liability early in the project life. This allows developers to monetize accelerated depreciation tax benefits without the use of tax equity, thereby further lowering financing costs.

As a result, reductions in total cost to government are not quite as large as reductions in incentive costs. Specifically, the cost to government of the interest tax deduction provided to the project for a TCP is roughly $1/MWh higher than that of the non-taxable cash production incentive due to the greater use of debt. Further, as the ITC and 1603 Cash Grant reduce the depreciable basis of a facility, while production-based incentives do not, the cost of depreciation benefits using a production-based incentive are about $2/MWh higher. Thus, the reduced cost to government of the TCP is in part offset by the increased use of existing investment tax benefits. For large wind, the total cost to federal and state governments of a $21/MWh TCP including accelerated depreciation and interest tax benefits is 21% lower than the total cost of the $22/MWh PTC (Figure 8).

Figure 7: Large wind policy options - costs and risks to federal and state governments

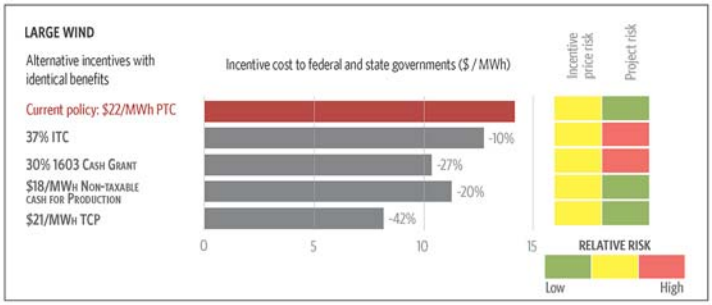
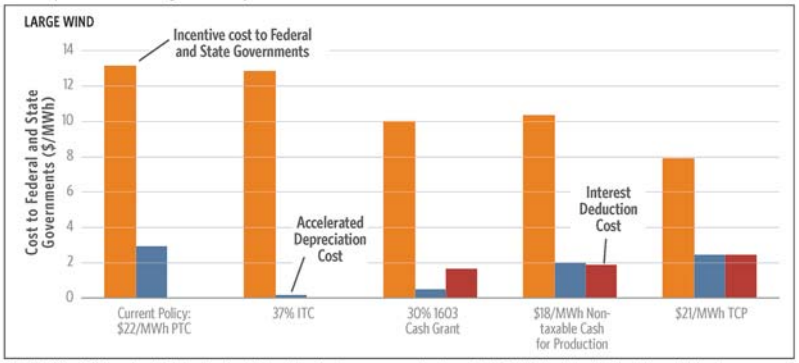


Figure 8: Cost of accelerated depreciation and interest deduction benefits to federal and state governments: Large wind facility in 2013. All scenarios deliver equal benefits to the large wind facility.



Note: The ITC and PTC case do not include project level debt and therefore have no government cost associated with the interest tax deduction at the project level.

Like BPC (2011) and BNEF (2010), we also found that the 1603 Cash Grant could be significantly more cost-effective than the PTC. Our estimated reduction in cost to government is roughly 25%, lower than BNEF's estimate of 50% per project. We believe that this difference is likely explained by:

- Our use of discounting by treasury interest rates to calculate costs to government rather than an undiscounted sum of nominal costs over multiple years.
- The difference in tax equity spreads from 2009-2011 relative to BNEF's calculation which considered tax equity market conditions for projects from 2004-2008.

5.3 Large Solar PV in 2013 and Incentive Price Risk

A TCP incentive could reduce government costs by 60% for a large solar PV facility, but the move to a fixed-price production incentive brings new risks to government.

The current 30% investment tax credit (ITC) for a large solar PV project in 2013 would cost federal and state governments $20/MWh. It would take a $36/MWh production tax credit (PTC) to deliver the same benefit; this would cost governments 13% more than the ITC. A 15% 1603 Cash Grant could provide the same benefit to the project and its investors for half the cost to governments of the ITC.

Cash incentives for production could reduce costs to government and, at the same time, allocate project cost risks to developers and investors. The TCP reduces costs to government across the range of projects analyzed, although the price level that provides equivalent benefits to the existing ITC varies depending on the project size and other characteristics. For example, a $22/MWh taxable cash incentive for production (TCP) could provide the same benefit to a large solar PV project in 2013 as the ITC, at 60% lower costs to government; while a $30/MWh TCP could provide the same benefit to a small solar PV project as the ITC, at 64% lower costs to government. Thus, the federal government could provide the same benefits to solar PV projects as the current 30% ITC, at lower unit cost, by offering a TCP in lieu of the ITC. The government would also benefit by shifting project performance risks back to the private sector.

However, this move would increase the incentive price risk borne by government. In general, when government sets the level of an incentive, it bears the risk that the level it sets may not be appropriate. This is particularly acute for production-based incentives, where government directly sets a price level. It is less problematic for the investment-based incentives because they scale with costs (though not directly with prices).

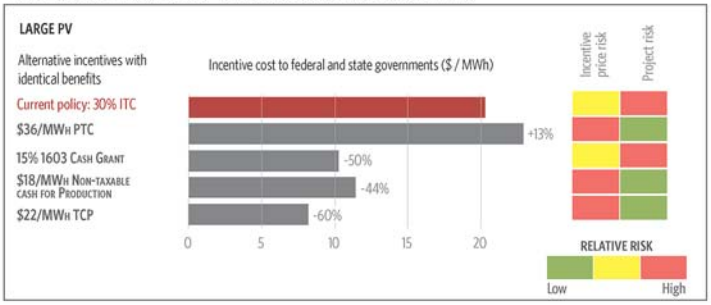
In both cases, if the government sets the incentive too low, it may not be enough to drive significant deployment. To the extent that state and ratepayer funds are able to make up the difference, this risk is somewhat mitigated in the U.S. However, as discussed in section 4, additional support for renewables from states and ratepayers is not likely in the near future.

If the incentive level is set too high, deployment may boom very quickly. This would result in ballooning costs that may be difficult to predict or control. This risk has been particularly problematic in the case of production-based incentives for solar PV due to rapidly evolving technology costs and performance (as well as the small lead times for deployment). This has been borne out by experience in Europe: Costs for solar PV feed-in-tariffs (FiT) and feed-in-premia (FiP) in Spain and Italy exploded due to much-higher-than-expected deployment driven by plummeting solar PV costs over the last few years, resulting in unexpected policy shifts which created subsequent industry busts. Solar PV costs have now fallen far below any historical nominal benchmarks. There is great uncertainty about the future cost trajectory and even significant variation in solar PV costs across geographies.

This risk is mitigated with current U.S. policy: a stable ITC in place until the end of 2016. Additional analysis would be needed to determine whether the savings associated with the TCP are sufficient to outweigh the increased risk associated with setting an appropriate price level. Absent this analysis, we cannot be sure the TCP would deliver net benefits to the government, relative to a 1603 Cash Grant.

For wind projects, the federal government already bears incentive price risks through the current PTC. Thus, a switch to the TCP involves no additional risk to government. Further, the price risk is less intense for wind than solar. While wind costs have come down substantially in the last two years, on balance, they have been relatively stable over the last decade. This has been borne out by recent experience: FiTs and FiPs for onshore wind in Europe have led to steady, cost-effective deployment over the last decade (see BNEF (2011) and Ragwitz et al. (2012)), and the PTC itself has supported steady deployment of wind in the U.S. since 2008. Note, however, that the European incentives all include mechanisms to reduce the subsidy level over time to account for and to incentivize cost reductions. Similar mechanisms could be applied to address this risk with a TCP.

Figure 9: Large solar PV policy options – costs and risks to federal and state governments



6 Conclusion and Recommendations

We used financial modeling of three representative project cases based upon cost, performance, and financing data for projects financed or deployed over the last three years to assess the impact and cost-effectiveness of federal policies. We found that:

Impact – Federal policies have played a crucial role in helping enable the recent boom in the deployment of wind and solar. They covered about half the gap between renewable energy costs and electricity market prices, enabling a six-fold increase in wind and solar generation in spite of a deep global recession. Recent reductions in the cost of electricity from wind and solar mean that the PTC alone (if extended) could fully bridge that gap for new large wind projects, and that the gap for solar has been significantly narrowed.

Cost-Effectiveness – Tax incentives are not the most cost-effective way to support renewable energy projects. Projects can only realize their full value if they can offset them with tax liabilities external to the project—a risk for investors which increases financing costs. Investment incentives can provide the same benefits to projects as production incentives at a lower cost to government. However, investment incentives shift some project risks to government. With both types of incentives, government bears some risk in setting the right level for the incentive. This risk is greater for technologies with rapidly shifting costs but can be better managed by investment-based incentives because they adjust with changing costs.

Potential Improvements – We find that a taxable cash incentive for production (TCP) would be more cost-effective than the PTC. Cash sidesteps the illiquid tax equity market. The production-based incentive allocates project cost and performance risks to private sector actors who are willing and able to bear them. In the event that the PTC is extended into 2013, our analysis suggests that the government could save more than 40% on incentive costs per MWh by delivering it as a TCP of $21/MWh over 10 years rather than a tax credit of $22/MWh.

Our work identifies two clear steps policymakers can take to improve the cost-effectiveness of federal renewable energy incentives:

1. **Extend the PTC as a taxable cash incentive for production (TCP)** – In the near term extend the $22 / MWh PTC for wind but deliver it as a $21 / MWh TCP. This would:
   - Maintain the same effective level of support for wind projects.
   - Reduce the cost of the incentive to federal and state government by around 40% for every unit of clean electricity generated.
   - Avert a bust in the wind industry, and stimulate deployment even in states or regions with no local or state policy supports.
2. **Give solar PV projects the option to take a 20% 1603 Cash Grant in lieu of a 30% ITC** – This option could increase the value of the incentive to the project while reducing the cost to government of providing it.

This analysis has important limitations which we hope to address in future work. We have not considered policy measures such as national renewable portfolio standards, reverse auctions, or cap and trade systems which rely on market mechanisms to set price levels. These mechanisms could be much more cost-effective in the long term if the gains in the economic efficiency of using markets to determine price levels are not offset by expense of incentive price volatility. As our previous work (CPI, 2011) suggested that incentive price volatility could lead to higher financing costs, it is an open question as to which policy option would be most cost-effective. We have also not considered options to eliminate the stop/start problems of temporary tax provisions (BPC, 2011).

Finally, a number of policy options have been proposed as alternatives or complements to current policy, such as the use of Master Limited Partnership or generalizations of Real-Estate Investment Trusts for renewable energy. The comparative cost-effectiveness of these proposals, and their interaction with the federal policy alternatives considered here, is another area for potential future work.

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Appendix A - Summary of Project Input Data, Assumptions, and Results

To address the importance and cost-effectiveness of federal incentives, we began by collecting data on the utility-scale renewable energy projects either financed or deployed in the U.S. over the last few years. We were able to obtain the following information for utility-scale, grid-connected solar PV and wind projects:

Technical details, costs, and timelines for a large sample of renewable energy projects - We used the median costs, timelines, and size of the large U.S. wind, small solar PV, and large solar PV projects financed or commissioned between 2009 and mid-2012 contained in Bloomberg New Energy Finance's (BNEF) proprietary renewable energy project database.

Historical performance of most large renewable energy generators - We based expected project performance on the monthly electricity generation reported by producers to the EIA for projects in operation for at least one full year between 2008 and 2011. We also used this data to estimate annual performance variation as well as variation in average capacity factor across facilities. We corrected the expected revenues based on time of use factors which we estimated using: the Eastern and Western Renewable Integration Studies for hourly resource variability, NREL's System Advisor Model to model varying generation, Bloomberg Terminal data and data from ERCOT, MISO, and FERC on hourly electricity pricing.[17]

Published ranges or examples of financial structures and requirements - We used a mix of academic work and publications by law and financial firms to compile prevailing financial structures, costs, fees, required equity returns, terms and conditions for renewable energy project financings.[18]

We were not able to obtain systematic, detailed information about the financing structure, revenues, or federal and state incentives used by specific projects. So we could not use statistical methods to assess differences across projects which may be attributable to policy.

Instead, we used the project cost and performance datasets to determine median characteristics of renewable energy projects (summary statistics are provided in Table A-1 below), and compiled them into three representative, generic project cases with median values for key technical characteristics – a large 130 MW wind farm (which comprised the majority of installed capacity), a small utility-scale 1 MW solar PV facility (majority of the installed projects), and a large 15 MW solar PV facility (the bulk of deployment growth). All projects were assumed to have achieved financial closure in mid-2010, roughly the mid-point of the range of project financing dates we studied. Key modeling assumptions for the three generic 2010 project cases are listed in Table A-2 below.

We assessed the impact of federal policy on these three cases in 2010 using financial modeling based on prevailing practice (as discussed in greater detail in Section 3), and present the results of that analysis in sections 4.1 and 4.2.

For the analysis of potential impact and cost-effectiveness in 2013 presented in section 4.3 and section 5, we modified the price, performance, size, and financial assumptions based upon reports on recent market conditions such as in US PREF (2012), Wiser et al. (2012), and Chadbourne & Parke (2012). The changes relative to the 2010 cases are:

- **Updated costs and performance for wind –** Our assumptions are based on work by LBNL and NREL on recent trends in wind turbine costs - http://eetd.lbl.gov/ea/ems/reports/wind-energy-costs-2-2012.pdf. Specifically, we use the average of the projected 2013 capacity factors and costs of all technology options expected to be available for a wind regime corresponding to our 2010 large wind case (roughly 6.5 m/s).
- **Updated size for large PV, and costs for small and large PV –** Large solar PV projects are getting even larger. We assumed a 60MW project size based on BNEF project data trends. We assume that U.S. utility-scale installations in 2013 can match Germany's average installed costs for

17 Note that we could not systematically link the majority of projects in the BNEF database to their EIA performance data.

18 Key data sources for information regarding prevailing terms for renewable project financing include: Mintz-Levin (2012) - http://www.mintz.com/publications/3055/, and NREL's REFTI survey - https://financere.nrel.gov/finance/REFTI on investor return requirements, US PREF - http://uspref.org/white-papers on tax equity transaction costs and current market conditions, LBNL (Bolinger et al.) - http://eetd.lbl.gov/ea/ems/reports/lbnl-2909e.pdf on tax equity structures.

small ground-mounted solar PV installations in mid-2012, about $2.20/W.

- **Lower tax equity costs for solar PV –** Due to reports of increasing volumes of solar PV tax equity financings (nearly $2.5 billion in 2011 according to Chadbourne & Parke, 2012), we have assumed that tax equity IRRs for solar PV will fall to roughly 50bp above those for wind by 2013.
- **Revised policy settings –** As the 1603 Cash Grant has expired, we assume that the ITC is the only option for solar PV in 2013. We assume the PTC for wind is extended at least to 2013.
- **Updated market price assumptions –** We use EIA projections for average wholesale market prices from EIA's Annual Energy Outlook 2012 reference case scenario.

The modified assumptions for the 2013 cases are also noted in Table A-2. Detailed results of the comparative cost-effectiveness analysis for 2013 scenarios discussed in section 5 are provided in Table A-3.

Table A-1: Summary Statistics of U.S. Renewable Project Data

Key Project Features	PV	Small PV	Large PV	Wind	Small Wind	Medium Wind	Large Wind
Project Size, Cost, and Timeline (BNEF)[1]							
Number of Projects in BNEF Data	332	267	65	326	54	116	156
Total Capacity in BNEF Data	1,774 MW	455 MW	1,318 MW	28,916 MW	288 MW	4,922 MW	23,706 MW
Size of Projects							
Low (P90)	0.8 MW	0.7 MW	6.0 MW	5.0 MW	1.5 MW	19.7 MW	99.0 MW
Mid (Median)	1.5 MW	1.2 MW	15.0 MW	78.2 MW	3.3 MW	42.0 MW	131.5 MW
High (P10)	14.9 MW	3.5 MW	38.8 MW	198.8 MW	10.5 MW	71.0 MW	207.8 MW
Overnight Costs							
Low (P10)	$3.6 / W	$4.3 / W	$3.2 / W	$1.5 / W	$1.5 / W	$1.8 / W	$1.6 / W
Mid (Median)	$5.7 / W	$6.0 / W	$4.2 / W	$2.2 / W	$2.1 / W	$2.3 / W	$2.1 / W
High (P90)	$8.3 / W	$8.5 / W	$5.4 / W	$3.0 / W	$3.1 / W	$3.5 / W	$2.6 / W
Duration of Construction (Median)	2Q	1Q	3Q	3Q	2Q	3Q	3Q
Duration of Development (Median)	2Q	2Q	3Q	6Q	6Q	4Q	7Q
Project Performance (EIA)[2]							
Number of Projects in EIA Data	53	43	10	548	173	183	192
Size of Projects							
Min	0.1 MW	0.1 MW	8.2 MW	0.8 MW	0.8 MW	13.0 MW	87.5 MW
Max	48.0 MW	5.0 MW	48.0 MW	735.5 MW	12.5 MW	85.5 MW	735.5 MW
Percentile Cutoff for Category		85%	100%		33%	67%	100%
Total Capacity in EIA Data	244 MW	60 MW	185 MW	39,265 MW	806 MW	8,026 MW	30,434 MW
Median Capacity Factor							
Low (P90 Median CF)	10.4%	10.8%	14.7%	19.7%	16.7%	19.2%	23.5%
Mid (P50 Median CF)	18.8%	18.0%	23.8%	30.0%	29.6%	29.1%	31.0%
High (P10 Median CF)	25.1%	24.6%	25.1%	37.8%	34.7%	39.8%	38.3%
P90/P50 Factor							
Low (P90 P90/P50 Factor)	75.2%	73.3%	93.2%	76.5%	74.0%	79.8%	76.9%
Mid (Median P90/P50 Factor)	95.0%	95.3%	94.8%	90.8%	90.4%	91.6%	90.6%
High (P10 P90/P50 Factor)	97.4%	97.4%	97.1%	96.0%	96.0%	96.5%	94.8%
P90 Capacity Factor							
Low	7.9%	7.9%	13.7%	15.1%	12.4%	15.3%	18.0%
Mid	17.9%	17.2%	22.6%	27.2%	26.7%	26.7%	28.1%
High	24.4%	23.9%	24.3%	36.3%	33.3%	38.5%	36.3%
TOU Adjustment[3]	121%	121%	121%	95%	95%	95%	95%

[1] BNEF data are summary statistics of estimates for overnight costs and project development and construction durations based on projects financed or commissioned from 2009 to mid-2012 where data was available. As BNEF data depend on publicly available information sources (such as regulatory filings, press releases, etc.), these estimates may be biased due to selection effects. We have not attempted to correct for such biases.

[2] EIA data are based on monthly generator data collected in EIA forms 923 and 860 and include only PV and wind projects which were operating for at least one year between 2008 and 2011.

[3] We estimated Time of Use (TOU) factors using: the Eastern and Western Renewable Integration Studies for hourly resource variability, NREL's System Advisor Model to model varying generation, Bloomberg Terminal data and data from ERCOT, MISO, and FERC on hourly electricity pricing.

Table A-2: Final Modeling Assumptions

	Small PV	Large PV	Large Wind
Project Cost & Performance			
Project Size (2010)	1.2 MW	15.0 MW	131.5 MW
Project Size (2013)[1]	1.2 MW	60.0 MW	131.5 MW
Project Cost (2010)	\$6.0m / MW	\$4.2m / MW	\$2.1m / MW
Project Cost (2013)	\$2.2m / MW	\$2.2m / MW	\$1.8m / MW
Construction Duration	1Q	3Q	3Q
Development Duration	2Q	3Q	7Q
Fixed Operations & Maintenance (O&M)	\$26 / kW-Year	\$17 / kW-Year	\$60 / kW-Year
Median Capacity Factor (2010)	18.0%	23.8%	31.0%
P90 Capacity Factor (2010)[2]	17.2%	22.6%	28.1%
Median Capacity Factor (2013)	18.0%	23.8%	38.7%
P90 Capacity Factor (2013)[2]	17.2%	22.6%	35.0%
First-Year Market Price Corrected for Time of Use (2010)[3]	\$68/ MWh	\$68 / MWh	\$53 / MWh
First-Year Market Price Corrected for Time of Use (2013)[4]	\$75 / MWh	\$75 / MWh	\$58 / MWh
Project Life	20 Years	20 Years	20 Years
Accelerated Depreciation	5-Year MACRS	5-Year MACRS	5-Year MACRS
Bonus Depreciation (2010 - none in 2013)	50%	50%	50%
Utility Discount Rate	8.25%	8.25%	8.25%

[1] Due to increasing PV project size for large solar PV projects expected to be built in 2013 observed in BNEF project data, we have chosen to consider a significantly larger project size for large PV in 2013.
[2] The P90 Capacity Factor is a more conservative estimate of capacity factor used by debt providers. The project should exceed it in nine out of 10 years it operates.
[3] Our expected wholesale electricity market prices for the 2010 cases are taken from EIA's Annual Energy Outlook 2010 reference case market price projections. Assuming 2% baseline inflation, these projections are consistent with 0.99% real market price escalation over the life of the project. Further, based on historical annual market price volatility, we assume that the P90 market prices used by debt providers are roughly 32% lower than expected market prices for both the 2010 and 2013 cases.
[4] EIA Annual Energy Outlook 2012 reference case market price projections are used for 2013 cases, corresponding to -0.14% real escalation relative to 2% baseline inflation.

	Small PV	Large PV	Large Wind
Financing Assumptions[4]			
Required Min Debt-Service Coverage Ratio (DSCR)	1.4x	1.4x	1.3x
Debt Term	10 Years	15 Years	15 Years
Term Debt Interest Rate	7.5%	7.0%	6.5%
Term Debt Closing Costs	2.4%	2.0%	2.0%
Construction Debt Closing Costs	\$0.1m	\$0.1m	\$0.1m
Tax Equity Closing Costs	\$0.5m	\$0.5m	\$0.5m
Tax Equity Syndication Fee	0.5%	0.5%	0.5%
Tax Equity Contribution (Unlevered)	60%	60%	60%
Tax Equity Contribution (Levered)	95%	95%	95%
Tax Equity Internal Rate of Return (IRR, 2010)	9.8%	9.8%	8.5%
Tax Equity IRR (2013)	9.0%	9.0%	8.5%
Sponsor IRR	10%	10%	9.3%
Lowest Cost Financing Structure (2010, Cash Grant)	Sponsor, Debt	Sponsor, Debt	Sponsor, Debt
Lowest Cost Financing Structure (2013, ITC for PV, PTC for Wind)	Unlevered Tax Equity	Unlevered Tax Equity	Unlevered Tax Equity

[4] Financing assumptions were drawn from Mintz-Levin (2012), NREL's REFTI Survey, US PREF (2011), Harper et al. (2007), Bolinger (2010), Moody's (2010), S&P (2009). Note that due to reports of increasing volumes of solar PV tax equity financings (nearly \$2.5 billion in 2011 according to Chadbourne & Parke, 2012), we have assumed that tax equity IRRs for solar PV will have fallen to roughly 50bp above those for wind by 2013.

Table A-3: Results of analysis of costs to federal and state governments: Current policy, and alternatives that deliver the same benefit to renewable projects

Large Wind	Debt	Equity	Tax Equity	Equity IRR	Tax Equity IRR	Flip Year	Final LCOE ($/MWh)	Incentive Level	Incentive Cost ($/MWh)	Change	Accelerated Depreciation Cost ($/MWh)	Interest Deduction Cost ($/MWh)	Total Costs ($/MWh)	Change in Total Costs
Current Policy: $22/MWh PTC, No Debt		40%	60%	9.3%	8.5%	11	46	$22/MWh	13.6	**0%**	2.5	0.0	16.2	0%
37% ITC, No Debt		40%	60%	9.3%	8.5%	11	46	37%	12.3	**-10%**	0.1	0.0	12.3	-24%
30% 1603 Cash Grant	31%	69%		9.3%			46	30%	10.0	**-27%**	0.5	1.3	11.7	-27%
$18/MWh Non-Taxable Cash for Production	48%	52%		9.3%			46	$18/MWh	10.9	**-20%**	2.0	1.9	14.8	-8%
$21/MWh TCP	52%	48%		9.3%			46	$21/MWh	7.9	**-42%**	2.5	2.5	12.8	-21%

Small PV	Debt	Equity	Tax Equity	Equity IRR	Tax Equity IRR	Flip Year	Final LCOE ($/MWh)	Incentive Level	Incentive Cost ($/MWh)	Change	Accelerated Depreciation Cost ($/MWh)	Interest Deduction Cost ($/MWh)	Total Costs ($/MWh)	Change in Total Costs
Current Policy: 30% ITC, No Debt		40%	60%	10.0%	9.0%	11	125	30%	31.3	**0%**	6.5	0.0	37.8	0%
$56/MWh PTC, No Debt		40%	60%	10.0%	9.0%	11	125	$56/MWh	35.4	**+13%**	12.7	0.0	48.1	+27%
14% 1603 Cash Grant	45%	55%		10.0%			125	14%	13.6	**-57%**	4.8	5.3	23.7	-37%
$24/MWh Non-Taxable Cash for Production	53%	47%		10.0%			125	$24/MWh	15.2	**-51%**	7.2	6.3	28.7	-24%
$30/MWh TCP	55%	45%		10.0%			125	$30/MWh	11.4	**-64%**	7.7	6.9	26.0	-31%

Large PV	Debt	Equity	Tax Equity	Equity IRR	Tax Equity IRR	Flip Year	Final LCOE ($/MWh)	Incentive Level	Incentive Cost ($/MWh)	Change	Accelerated Depreciation Cost ($/MWh)	Interest Deduction Cost ($/MWh)	Total Costs ($/MWh)	Change in Total Costs
Current Policy: 30% ITC, No Debt		40%	60%	10.0%	9.0%	11	83	30%	20.3	**0%**	1.1	0.0	21.3	0%
$36/MWh PTC, No Debt		40%	60%	10.0%	9.0%	11	83	$36/MWh	22.9	**+13%**	5.2	0.0	28.1	+32%
15% 1603 Cash Grant	50%	50%		10.0%			83	15%	10.2	**-50%**	3.0	5.5	18.7	-12%
$18/MWh Non-Taxable Cash for Production	58%	42%		10.0%			83	$18/MWh	11.4	**-44%**	4.7	6.1	22.2	+4%
$22/MWh TCP	60%	40%		10.0%			83	$22/MWh	8.2	**-60%**	5.1	6.7	20.0	-6%

Appendix B - Modifications to CPI Financial Model for this analysis

The model used in this this analysis is a modified version of the financial model previously developed by CPI to support case study analysis of the impact of policy on the financing of renewable energy projects.[19] That model took as input the technical, financial, and policy characteristics of a project and calculated all cash and tax flows to and from the project over its useful life. The model was used to address two questions closely related to those we are considering here:

How did policy contribute to the actual costs and returns of a specific project? Given a specific project, the relevant policy supports, details of the actual financing structure used, and estimates of the revenues expected, the modeled cash flows were used to calculate financial metrics such as the project's internal rate of return (IRR), debt service coverage ratio, the returns to equity investors, and the contribution of policies to the cost of electricity.

How would project costs vary under different policy scenarios? For a specific project in a given policy environment, the cash flow model could also be used to numerically calculate the revenue required to meet the combined return requirements for all equity investors while simultaneously maximizing the leverage (the level of project debt) – a slight variant of the usual levelized cost of electricity for the project. By varying only the policy environment and computing the change in levelized costs, we can assess the impact of policy on the cost of financing the project.

The previous model did not have the tax equity financing detail needed to perform comparative analysis of U.S. federal incentives, nor did it have the capacity to address the cost of government of providing financial support to projects. We modified the model in several ways to address these issues:

Direct calculation of a variant of the usual levelized cost of electricity. The levelized cost of electricity is usually defined as the revenue per unit of electricity generated needed to achieve a project IRR equal to the weighted average cost of capital for the project. The weighted average cost of capital is generally provided as an input and depends on the required equity return and the leverage (along with the cost of debt). For this analysis, we have data on required after-tax returns for various investors, but rather than leverage, we have general information about the terms, conditions, and costs of debt and tax equity financing. We built a levelized cost calculator that determines the minimum revenue needed to meet the equity return requirements of both the developer and a potential tax equity investor. However, it does so while adjusting certain tax equity financing parameters and optimizing the leverage to meet a required minimum debt service coverage ratio. So our levelized cost is a function of required equity return, debt-service coverage ratio, and certain tax equity and debt costs and fees rather than equity return and leverage.

Added tax equity details. We added options to model the tax equity project financing structures used by project developers to bring in outside tax investors to help them monetize the tax benefits provided by federal incentives. These options are the parameters and conditions describing the allocation of tax and cash benefits among tax equity investors and sponsors over the life of the project, and are constrained by IRS rules as well as industry practice.[20]

Optimized tax equity structure for levelized cost calculation. We modified the levelized cost calculation to adjust the tax equity structure to minimize the revenue required to simultaneously meet the return requirements of both tax equity investors and sponsors while maximizing the leverage.

Added calculation of cost to government of various policy supports. We added the capacity to calculate the cost to government (either in the form of direct payments or foregone tax revenues) of policy supports utilized by the project (such as grants, tax credits, accelerated depreciation, or deductions of interest expenses). Specifically, this cost is calculated as the present value of all flows to government discounted using zero-coupon treasury yields of the appropriate tenor. That is, we are assuming that any impact on government cash flows

19 Described in Appendix A.1 of http://climatepolicyinitiative.org/publication/the-impacts-of-policy-on-the-financing-of-renewable-projects-a-case-study-analysis/.

20 We relied heavily on the recent work of Mark Bolinger and collaborators at LBNL and NREL regarding the specific tax equity structures used (see, for example - http://eetd.lbl.gov/ea/ems/reports/lbnl-2909e.pdf).

is marginal and therefore must be financed through a government debt transaction (either the purchase or sale of a treasury). Note that since we are computing costs to all levels of government, this is implicitly assuming that marginal shifts in state government finances are enabled by transfers from the federal government.

Generalized levelized cost to allow variation of policy supports. In order to compare the cost to government of different federal incentives which deliver the same cost of electricity to ratepayers, we modified levelized cost calculation to allow the revenues needed to meet financial requirements to arise (at least in part) from specific policy sources such as investment or production tax credits.

Mr. CASTEN. There specifically is a rich discussion in here about the benefits of using cash incentives as opposed to tax credits, which you talked about. Can you give us a little bit of an education on the differential ways that cash incentives versus tax incentives drive investments in clean energy?

Mr. HARVEY. Certainly. So whenever you give somebody cash, they get a $1 worth of benefit for every $1 you give them. If you give them a tax credit, they have to find a way to use that tax credit. And most startups and most new technology companies don't have profits, or don't have excess profits, so they don't need the tax credit, so they sell it on a secondary market. The price of that tax credit is always going to be less than $1, because of transaction costs. In many cases, because of restrictions on the tax credit, it is as low the 50 cents, which means the Federal Government is getting 50 cents for every dollar it gives up. That is a terrible bargain.

So the answer is either direct grants, or highly fungible, highly liquid tax credits.

Mr. CASTEN. Thank you. I wish I had more time, but I think I am out.

Ms. CASTOR. And we will ask Mr. Harvey to get back to the committee with greater detail on that point.

At this time, I recognize the ranking member.

Mr. GRAVES. Thank you, Madam Chair.

Dr. Liverman, thanks again for being here. You made reference to IPCC and Paris Accord earlier. Do you believe that the metric measuring China and India's emissions is the appropriate one meaning including GDP or an economic unit as opposed to an absolute reduction?

Dr. LIVERMAN. I think we need to use all of the measures to assess what is happening in China, whether it be their absolute emissions, their historic emissions, their carbon intensity. Most scientists will look at all of those.

Mr. GRAVES. So just doing economic is not an appropriate metric?

Dr. LIVERMAN. I think the research suggests that we should look at multiple metrics because each metric gives us a different insight into what China's doing and where it is going.

Mr. GRAVES. Thank you. Number two, I want to make sure I understood what you said before, so please correct my statement if I get this wrong, but you made mention of the greenhouse gas concentrations in the environment and talked about how much of that is attributable to what we released over the last 50 years. And so, I want to take it a step further and make sure I got this right. So there is sort of a momentum within the environment of these greenhouse gases. And so, effectively, if we could stop all emissions today in the United States, and those concentrations that are there are there. And so the corresponding temperature changes would result because of those greenhouse gas concentrations that are in the environment from previous emissions, is that accurate?

Dr. LIVERMAN. Yes, unless, of course, we look at what the IPCC calls the negative emissions. And the discussion that we had so far has focused very much on the technology of carbon capture and storage, this sort of new technology, but we have very long-standing technology of carbon capture and storage which is forestry and farming for carbon capture.

Mr. GRAVES. Biogenics, yeah.

Dr. LIVERMAN. And so, that we could make a dent in the emissions that are already there, and the U.S. can play a major role if we manage our forests and manage our farmland in order to capture carbon.

Mr. GRAVES. I read an interesting article this week, I think it was the Salk Institute on how they are working on plant technology in order to increase the sink that results. In fact, I used to work on coastal resiliency issues. We were looking at how to change the vegetation in some of our diversion, water diversion receiving areas, to increase the uptake of phosphates and nitrates to help reduce the dead zone that was occurring, the hypoxic conditions in the Gulf of Mexico. So I agree there are other technologies and I think some of the extraction of carbon capture utilization are important ones.

Do you believe that we should be using a metric of looking at sort of best return on investment whenever we make recommendations ultimately out of this committee, looking at which recommendations are going to get best return on investment in terms of preventing temperature increases and preventing sea rise and things along those lines?

Dr. LIVERMAN. Yes, we need a metric of return on investment, but I would say that IPCC and many other scientific assessments do identify the challenge of putting a financial cost on some losses, loss of life, loss of farms.

Mr. GRAVES. Sure.

Dr. LIVERMAN. Loss of infrastructure. It can be quite hard to put a dollar value on that. And also, the uncertainty about discounting the future.

Mr. GRAVES. But it is important for us to use some type of metric in looking at jobs, at economic and return on investment and others.

Dr. LIVERMAN. Yes, yes.

Mr. GRAVES. Thank you. Moving on. Mr. Harvey, I want to—you talked a lot about renewables. You talked about wind and solar and others, and certainly those are important all-of-the-above strategies or components of a comprehensive strategy. But you didn't talk about storage, and obviously, that is an important part, the sun doesn't shine at night, right? And so I was looking at some statistics the Manhattan Institute put together, they determined that the gigafactory, Tesla's gigafactory, the largest battery manufacturing facility in the world. That its annual production is capable of storing 3 minutes of U.S. energy. If they produced batteries for a 1,000 years we would be able to store enough energy for 2 days in the United States. Fifty to 100 pounds of rare Earth materials are mined for every 1 pound of battery. How do you reconcile that and the environmental impacts? And let's keep in mind 15 of the top 23 commodities we are importing, minerals we are importing, including rare Earth, are actually from China, Russia and other countries like that, or China and Russia alone are involved in providing those materials to the United States.

Mr. HARVEY. So electricity storage and batteries is really expensive, and it is true we are not going to get to long-term grid scale battery storage at a cost-effective number any time soon. Fortu-

nately, we don't need to, there are half a dozen strategies to balance the grid given variable renewables. I mentioned wheeling power. The grid is a kind of battery because we never have the same demands across the United States or the same supplies. We need to use some of our other resources better. The Bonneville Power administration uses its hydroelectricity for bulk power instead of peaking power. That is economically insane, right? We should use it at its highest value use.

Onshore wind has a different operating regime than offshore wind. Offshore wind operates much longer and for different times. So the more varieties you have, and the more they are hooked together, the less you need battery storage. All that said, I think storage is one realm where we need to do a lot of R&D, and we can use spot storage to alleviate tensions and problems on the grid. But your main point about bulk storage is correct.

Mr. GRAVES. Madam Chair, I want to ask unanimous consent to include in the record a graphic from the Manhattan Institute that indicates that $1 million invested in shale and $1 million invested in solar and wind would actually produce at least six times as much energy over a 30-year period as compared to just wind or solar.

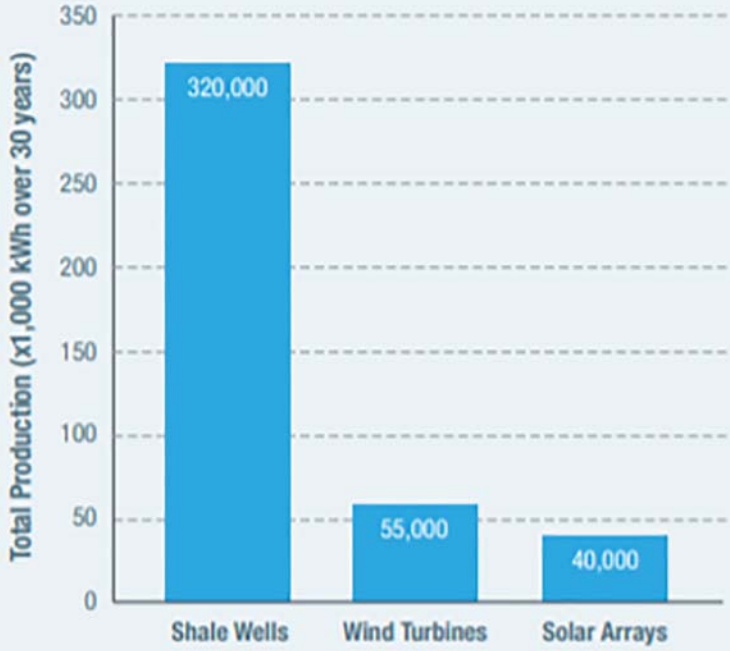
I yield back.

Ms. CASTOR. Any objection? And I failed to rule on Mr. Casten's unanimous consent request. So without objection, we will admit into the record Mr. Casten's material and the ranking member's material.

[The information follows:]

FIGURE 2.

Total 30-Year Electricity Production from $1 Million in Hardware: Wind Turbines, Solar Arrays, and Shale Wells



Source: Lazard, "Lazard's Levelized Cost of Energy Analysis," 2018; Gulfport Energy, Credit Suisse Energy Summit, 2019; Cabot Oil & Gas, Heikkinen Energy Conference, Aug. 15, 2018

Ms. CASTOR. At this time, Mr. Neguse, you are recognized for 5 minutes.

Mr. NEGUSE. Thank you, Chairwoman Castor, thank you for holding this important hearing. Thank you to the witnesses. I reviewed your testimony, your written testimony as well as I know my colleagues have, and found each of you, in your respective testimonies, to be incredibly helpful and thoughtful, and certainly educational for us and our work, so I appreciate the work that you have done.

I would say with respect to the ranking member's comments, and I certainly appreciate them regarding energy storage, begs perhaps

the larger question, for this committee and for this Congress to debate, which is to say, why not invest more resources in research on energy storage, and that seems to be an area where there is some bipartisan support. And I appreciate the Chamber of Commerce's written testimony in terms of recommending increased investments in ARPA-E and so forth, which I imagine can be incredibly productive from an energy storage standpoint. So I hope that my colleagues would join us in that effort.

I am a FERC nerd as well, and so, like Mr. Armstrong and Mr. Casten, I wanted to talk to you, Mr. Harvey, a little bit about your recommendations. Before I do so, I do just want to touch on a comment made by Mr. Carter at the beginning of hearing, with you, Mr. Guith—I hope I am pronouncing that right, my name is a tough one, so—my understanding of Mr. Armstrong's comment was essentially that Federal standards, or international standards, for that matter, from a renewable energy standpoint, that those could have unintended consequences and they could impede economic growth and so that is why, perhaps, some folks on the other side of the aisle oppose them and perhaps your organization as well. Am I understanding that right, that exchange?

Mr. GUITH. No. I made the point that policymakers have to be careful in how they develop policy, because there could be especially as relates to climate far-reaching impacts. I mean, the example that we were discussing is focusing on one specific type of non-emitting energy that might therefore have a negative impact on another non-emitting energy. In that case it was nuclear.

Mr. NEGUSE. I appreciate your response. What I would was say is part of why I am struggling, and I suspect my colleague, maybe my colleague, Representative Huffman, feels the same way, is some your written testimony seems to indicate, in fact, a preference for some of these standards. A good example of this is the Kigali Amendment, right? An amendment that has been ratified by 66 countries, that a variety of business entities in our country are advocating for passage of here, right, because we know there would be a substantial economic impact in terms of the tens of thousands of jobs that would be created by virtue of committing to the reduction 80 percent over the next 30 years of HFCs, right? Billions of dollars of economic impact here in the United States. And so, I guess the point I am making is that standards imposed at the Federal level or by international agreement can be quite a boon to our economic growth. And I would hope the Chamber would appreciate that given that you all have been very supportive of the Kigali Amendment.

Mr. GUITH. I think it is a great example where the business community was involved, so that policymakers understood what was achievable, versus what was hypothetical. And that is why I think you got to a point with Kigali, where it was a win-win across the board. And that is why, I mean, to go back to Mr. Huffman's original question, I mean the Chamber hasn't changed. Certainly, the business community has evolved, but we have been pushing for these types of advanced technology investments certainly since I have been involved with the Chamber a decade ago. I mean, without developing these technologies, if you go back 50 years——

Mr. NEGUSE. I appreciate your comments. I don't want to interrupt. I would say in Representative Huffman's defense, while I certainly can't speak to the Chamber's activities in the last 10 years, and I am new to Congress here for all told of 112 days, I suppose, I think that the Chamber has had a long history that has been well documented in terms of opposing a variety of different important legislative efforts at the congressional level to try and move the needle in the fight against climate change. But as I said, I appreciate your support to the Kigali Amendment and hope you can join many of my colleagues here in the Congress that are urging the Trump administration to agree with the vast majority of the international community that are pushing on that front.

Mr. GUITH. We have, voicefully.

Mr. NEGUSE. Thank you. Mr. Harvey, with respect to FERC, just following up on the point that Mr. Casten made, your written testimony articulates, I think, in an effective way, the realities of the ways in which FERC has been far from technology neutral, and I guess I am curious, what recommendations you believe we should take in terms of trying to give FERC that better, quote, unquote "instruction" that you referred to in your answer to Mr. Casten.

Mr. HARVEY. I will first acknowledge it is difficult to specify a set of rules that are going to guide all future rulemaking. But I do think emphasizing again that it is the FERC's requirement to be technology neutral to set performance standards, that the performance standards should be based on an explicit physical or economic need. Not one that is made up. It might be worthwhile for the FERC to have a scientific or technical advisory board made up of utility engineers and national lab experts, something like that to ascertain whether the decisions they made are made for a thumb on the scale reason, or for system balancing and legitimate purpose. But you do not want the Federal Energy Regulatory Commission to be the handmaiden of a certain industry. It will wreck our electric system in the long run and it will impose unnecessary costs.

Ms. CASTOR. Thank you.

Mr. McEachin, you are recognized for 5 minutes.

Mr. MCEACHIN. Thank you, Madam Chair. Let me start by apologizing to you. We had a hearing on robocalls in Energy and Commerce. It was a bit repetitive, but there we were, so I apologize for my tardiness.

Mr. Foster and Mr. Harvey, I am hopeful that the House of Representatives will consider infrastructure legislation in the next few months. To that end, Mr. Foster, your testimony has discussed the importance of investing in energy efficiency and infrastructure, both of which spur economic development. What would you prioritize for investments and why?

Mr. FOSTER. Well, in terms of energy infrastructure, I think almost any investment that you make is going to create good, high-paying jobs in the energy sector, the transmission distribution and storage system has almost three times the unionization rate of any other part of the private sector. So you are dealing with highly skilled, highly trained construction workers, good-paying jobs. So rebuilding a transmission, expanding transmission to allow more renewables onto the grid, a whole range of those kinds of activities

will be very good for the economy, lowering energy costs and very good for job creation.

So, especially, if you were to prioritize areas that have been negatively impacted by some of the changes that we have experienced in our evolving energy technologies, that would be a great place to start.

I will just repeat again that we have, in the loan program office, $39 billion worth of unused loan authority that with the proper supervision, could be used to jump-start a big energy infrastructure spending program in America.

Mr. MCEACHIN. Thank you for that. Mr. Harvey, what about you? What should the infrastructure bill include to make a dent in our greenhouse gas pollution?

Mr. HARVEY. One element I would propose is expanding transmission lines across the country to help balance renewables and balance the whole system. In fact, I think we should look at ways to streamline permitting. I advocate pre-zoning into red, yellow and green zones, where red, you are just not going to build anything; green, you get a permit in 90 days if you meet the proper specs; and yellow is like everything today, it is an all out war. So we just need to clean that up and save a lot of time and a lot of trouble.

I would recommend extending tax credits for clean energy, a bunch of them are set to taper down, starting now. Right when we are building momentum, that is the wrong time to do that. So I would push those back another 5 years or something like that. I think also we need to look at transportation. One interesting opportunity would be to offer matching funds to utilities to build an electric vehicle charging infrastructure. And in general, transportation infrastructure, one of the iron laws of transportation is if you build it, they will come. If you add freeway lanes, you get more cars. If you add things like bike paths, you get more bikes. There is a revolution in transportation options which we should take advantage of what they call micromobility to bikeshare to autonomous vehicles, or electric vehicles. We neglected our transportation infrastructure for decades now, and it is starting to fail us. And that is going to be very costly to the American economy.

Mr. MCEACHIN. Let me ask you as quickly as I can about your red, green, and yellow pre-zoning, is that what you called it?

Mr. HARVEY. Yes.

Mr. MCEACHIN. I experienced that problem in Virginia with local governments, a particular area loses its coal industry, but when we try to put up a wind farm, they are concerned about their view shed. So I understand some of the problems, with zoning particularly in your red area—I mean, in your green area, are you saying to those areas no matter what their zoning laws are, we can come in? Explain to me how that would work in 1 minute and 3 seconds?

Mr. HARVEY. The cognizant jurisdiction, be they local, State, or national, need to set whatever standards they want to set. But then, if in a green zone a project meets those standards and gets a permit in 90 days.

Mr. MCEACHIN. I see.

Mr. HARVEY. I saved you 48 seconds.

Mr. MCEACHIN. There you go.

Madam Chairwoman, I give you 45 seconds back.

Ms. CASTOR. Very good. Thank you, Mr. McEachin. Mr. Palmer, you are recognized for 5 minutes.

Mr. PALMER. Thank you, Madam Chairwoman. My question is for the entire panel. If the United States completely eliminated its carbon emissions, would that stop global climate change?

Mr. FOSTER. If the question is "we," meaning the United States of America, if we did that, the answer is no, it clearly wouldn't.

Mr. PALMER. If the entire world stopped its carbon emissions, would that stop global climate change?

Dr. LIVERMAN. No. We have some built-in warming, but if we focused also on taking carbon out of the atmosphere, it could do so.

Mr. PALMER. Have we ever seen a case where sea levels rose more than are predicted, for instance, by the scientists now?

Dr. LIVERMAN. My understanding is that what we are observing is consistent with what the science had projected, but sea level rise does take a number of years. So much of that is still to come.

Mr. PALMER. Well, the reason I ask that is apparently, some folks take as the gospel truth whatever these esteemed scientists project in, for instance, in his book, Farewell to Ice, Peter Wadhams, a professor of ocean physics at Cambridge University, predicted that polar ice and the Arctic would be gone by mid decade. Not only is the ice still there, but at points in 2012 and 2016, it actually increased by about 50 percent. It went from 2.2 million square miles to 3.3 million square miles. So I guess my question is, do each of you believe that the science on climate is settled?

Dr. LIVERMAN. The science on climate has reached considerable consensus. There is still areas where we are not completely clear about what is going to happen, partly because we don't know what policies we are going to pursue. And with regard to using one paper, one of the things——

Mr. PALMER. That is not one paper.

Dr. LIVERMAN [continuing]. That the IPCC tries to do is to look at a whole range of research papers and assess and judge what those say collectively, rather than looking at just one paper.

Mr. PALMER. And it is not just one paper. There are a number of—there is a number of examples that indicate that the science is not completely settled. Although, I think the consensus is, is that the climate is changing. I am not sure that the consensus is that it is all anthropomorphic. I am certain it is not the consensus that it is all anthropomorphic, and when we talk about eliminating all carbon emissions from the United States in the next 10 years, even Senator—former Secretary of State John Kerry admits that that will not mitigate climate change, it will not mitigate warming, basically has us standing alone. And there are obviously consequences for the policies that we develop.

In California right now, there is a lawsuit that has been filed by minority group against the California Air Resources Board, because of the harm that it is doing to low-income people. Since the effective date of California's greenhouse gas reduction law, the Global Warming Solutions Act, 41 States have reduced their per capita greenhouse gas emissions more than California, but it had enormous negative impact on people in California. So, I think, we have got to look at this in the broader spectrum of how this affects ev-

erybody, and the U.S. obviously I think we continue the best in the technologies to reduce our carbon emissions. I am all for that.

I think we have to look at the whole picture of climate change, because I think that natural variation is going to be the bigger factor in this. And if we are not taking steps to engineer solutions, use our technology engineer expertise to adapt and mitigate, and we just focus on the carbon side of things, we are going to be in big trouble. We will not be prepared for the consequences of that inaction.

Dr. LIVERMAN. I would agree, and so would IPCC, and the National Climate Assessment that we need to do a lot to focus on how we cope with extreme climate and global warming, whilst at the same time, looking at reducing our carbon emissions. The importance of adaptation is very important, both for the disadvantaged and for businesses across the United States.

Mr. PALMER. Well since I got an agreement, I will yield back.

Ms. CASTOR. Well, I want to thank the witnesses here today I think you helped us set the table, Dr. Liverman, to review the—your work and the scientific consensus across the globe that we are not on track to reducing carbon emissions. Yes, we must and we will have hearings focused on solutions regarding adaptation and mitigation, but there is simply not a substitute for tackling the source of the problem, and that is the increase in greenhouse gases. So thank you to the witnesses for your testimony. And the committee is adjourned.

[Whereupon, at 11:53 a.m., the committee was adjourned.]

United States House of Representatives Select Committee on the Climate Crisis

Hearing on April 30, 2019 "Solving the Climate Crisis: Drawing Down Carbon and Building Up the American Economy"

Questions for the Record

Dr. Diana Liverman, Regents Professor of Geography and Development, University of Arizona

DEAR CONGRESSWOMAN CASTOR: Thank you for your letter with follow up questions about my testimony before the Select Committee on the Climate Crisis on Tuesday, April 30, 2019. It was a privilege to meet you and the committee and receive such thoughtful and important questions. I provide answers to the questions below, including some research that has been published since the release of the IPCC 1.5°C report.

Sincerely,

DIANA LIVERMAN,
Regents Professor of Geography and Development, University of Arizona.

THE HONORABLE KATHY CASTOR

1. Is the US emissions trajectory consistent with limiting warming to 1.5°C or even 2°C?

The most recent research shows that the US emissions trajectory is not consistent with limiting warming to 1.5°C or 2°C.

The IPCC Special Report on 1.5°C (August 2018) did not examine emissions by country. The report does assess the consistency between the current Paris commitments (NDCs or Nationally Determined Contributions) and scenarios that would limit warming to 1.5°C, and concludes that the full implementation of the current Paris commitments would produce a global average temperature increase by 2100 of 2.9–3.4°C (5.2–6.1°F) above preindustrial levels at 66% probability.

IPCC finds that there is high agreement that the current Paris commitments are not in line with pathways to achieve either a 1.5° or 2°C target.

The UNEP Emissions Gap report (November 2018) supports the 2.9°C–3.4°C of warming estimate by 2100 under a scenario where Paris commitments are fully implemented.

UNEP reports that US emissions decreased from 2004 to 2017, and in 2017 were 13.1% of total global greenhouse gas emissions. UNEP states that the United States Paris target was to reduce emissions 17% below 2005 levels by 2020, and 26–28% by 2025, but noted that with the current intention to withdraw from the Paris agreement the US is unlikely to meet either target.

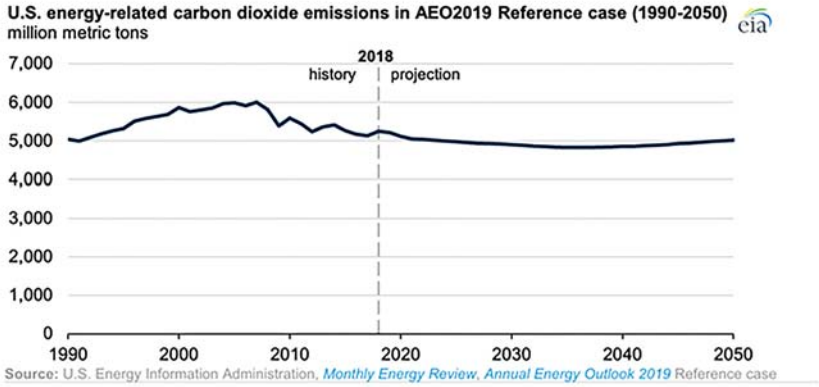
The latest analysis of the Global Carbon Project (Dec 2018) estimates that global carbon dioxide emissions rose by 2.7% between 2017 and 2018, projecting US emissions as 2.5% higher in 2018 than 2017 after several years of decline as coal was displaced by gas, solar and wind.

The US Energy Information Administration (USEIA) Monthly Energy Review for May 2019 reports that energy related carbon dioxide emissions, which were around 6 billion metric tons in 2005, had fallen to 5.17 billion metric tons in 2017, a reduction of 14.4% from 2005 and approaching emission levels for 1990 (5.04 billion metric tons). However, 2018 reversed this trend increasing by 2.7% over 2017 to 5.26 billion metric tons.

In March 2019 the USEIA Annual Energy Outlook projected that US energy consumption will remain near current levels of 5 billion metric tons through 2050 (see figure below) if there are no changes in laws and regulation and if current trends shifting from oil and coal to gas consumption continue.

MARCH 20, 2019

EIA projects U.S. energy-related CO2 emissions will remain near current level through 2050



Source: U.S. Energy Information Administration, *Monthly Energy Review*, *Annual Energy Outlook 2019* Reference case

Carbon dioxide emissions from U.S. energy consumption will remain near current levels through 2050, according to projections in EIA's *Annual Energy Outlook 2019*. The AEO2019 Reference case, which reflects no changes to current laws and regulations and extends current trends in technology, projects that U.S. energy-related carbon dioxide (CO2) emissions will be 5,019 million metric tons in 2050, or 4% below their 2018 value, as emissions associated with coal and petroleum consumption fall and emissions from natural gas consumption rise.

Some recent studies (e.g. America's Pledge Initiative on Climate 2018, Kuramuchi et al 2017) suggest that *actions by non-Federal actions by states, cities and business could contribute to emission reductions of up to 21% below 2005 levels by 2025,* approaching the Paris reduction commitment of 26–28% even without new Federal policies.

The IPCC 1.5°C report concludes that for a chance of limiting warming to 1.5°C, global CO_2 emissions must decline by about 45% from 2010 levels by 2030, and reach net zero emissions by 2050. For 2°C emissions would need to decline by 20% between 2010 and 2030 and reach net zero around 2075.

According to the Energy Information Administration, US CO_2 emissions from energy consumption were about 6 billion metric tons in 2010. To be consistent with the IPCC 1.5°C pathway, and if the US were to follow this global average pathway, emissions would need to decline to 3.2 billion metric tons by 2030. Given that we are now in 2019, and emissions are at 5.3 billion metric tons, energy related emissions would need to decline annually by at least 3–4%.

Finally, the research literature on responsibility for emissions suggests that the U.S. should be making even steeper cuts than the global average because of our historical responsibility for emissions and high per capita current emissions (e.g. Holz et al, 2018; Van Den Berg, 2019). Carbon dioxide, once emitted, has a long residence time in the atmosphere (between 20 and 200 years according to IPCC) and thus some analysts believe that cumulative emissions should be the basis for emission reductions. This implies that those having greatest historical emissions making greater cuts. The US is the largest historical emitter with responsibility for around 25% of accumulated CO_2 emissions, compared to 12% for China (WRI 2019).

2. Please provide more information on the economic damages associated with global warming of 1.5°C and 2°C and how many dollars of those damages might take place in the United States?

Assessing the economic damages of global warming is extremely challenging. They depend on detailed and robust estimates of the impacts across regions and for key sectors such as agriculture, coastal infrastructure, and health, and assumptions about how to convert non-market impacts, such as those on ecosystems and disease, into dollar values. Results also vary with assumptions about discount rates and future economic growth.

The IPCC 1.5°C report discusses several major studies of economic damages. First, Warren et al (2018) estimate that by limiting warming to 1.5°C rather than 2°C damages are reduced by 22% (range 10–26%) and are reduced by 87% (range 74% to 91%) compared to the current trajectory that would take warming to 3.5°C. Damages included are costs associated with climate change-induced both market and non-market impacts, impacts due to sea level rise, and impacts associated with large scale discontinuities This the source of the $54 trillion at 1.5°C and $69 trillion at 2°C estimates of the IPCC, and also estimates cumulative damages of $551 trillion if temperatures rise to 3.7C by 2100. Global GDP in 2017 was about $80 trillion, of which the US was responsible for almost 25% ($20 trillion). *If losses were equally distributed and proportional to GDP then the damages to the US, based on this paper, would be about $13 trillion at 1.5°C and $16.6 trillion at 2°C by 2100, compared to more than $130 trillion at 3.5°C.*

IPCC also discusses research by Burke et al (2018) that finds that "limiting warming to 1.5°C instead of 2°C would save 1.5–2.0% of Gross World Product (GWP) by mid-century and 3.5% of gross world product (GWP) by end-of-century". Under a 3% discount rate this corresponds to avoided damages of $8.1 trillion—$1.6 trillion by 2050, and $38.5 trillion by 2100 (this is the source of the number included in my original testimony).

More recent research by Jevrejeva et al (2019) examines the global economic costs of coastal flooding and conclude that annual global flood costs will be $10.2 trillion a year (1.8% of GDP) in 2100 at 1.5°C (projecting .52m of sea level rise) and 11.7 trillion (2% GDP) under a 2°C scenario (projecting .63m of sea level rise) if no further adaptation is undertaken. *The US annual flood cost is reported as $394 billion a year at 1.5C (0.9% of GDP) and 446 billion at 2C (1% of GDP)*

IPCC discusses two studies focusing only on the USA which find that economic damages are projected to be higher by 2100 if warming reaches 2°C than if it is constrained to 1.5°C. The first study is that of Hsiang et al. (2017) concluded that *the USA could lose 2.3% Gross Domestic Product (GDP) each year per degree of global warming. They find that the baseline if no further action is taken to reduce emissions results in economic damages reaching 4.5% (range 2.5% to 8.5%) of GDP per year by 2100. Avoided damage from achieving a 1.5°C temperature limit is 4% of GDP (range 2.0%–7.0%) by 2100. Avoided damages in the US from achieving a 2°C temperature limit are 3.5% of GDP (range 1.8%–6.5%). The second study by Yohe*

(2017) finds an annual GDP loss in the US of 1.2% per degree of warming, or approximately 0.6% for a half a degree increase from the current 1°C warming to 1.5°C.

Economic damage estimates for the US are also provided in the 4th US National Climate Assessment (NCA4). The technical report for NCA4 (EPA 2017) compares annual economic damages in 2090 for two IPCC scenarios, RCP8.5 which approximates to a no further action scenario (e.g. a 3.5°C (range 2.6–3.8) global warming by 2100) and RCP4.5 which approximates to a 2°C (1.1 to 2.6) scenario (by 2100). Damages are estimated for sectors that include air quality, extreme temperature mortality, loss of labor, health, agriculture, infrastructure, energy and fisheries. For example, *annual damages in 2050 under the RCP4.5 (2°C) scenario include $6.9 billion in air quality, $32 billion from extreme high temperature mortality, $35 billion in lost labor hours, $1.8 billion to fisheries, $9.5 billion to roads, bridges and rail, and $69 billion in damage to coastal property. This totals $154 billion and rises to $262 billion in annual damages by 2090. $56 billion (85%) of the coastal property losses estimated for 2050 under the 2°C scenario would occur in the Southeastern United States if no further adaptation occurs.*

Since this question was asked Representative Levin from California's 49th congressional district, I include a regional example of damages to the US from the recent California Climate Assessment (August 2018, Appendix B). The estimates of economic damages to different sectors in California by the middle of this century (2050) due to climate change include those to health from high temperature mortality ($50 billion a year), transport ($1 billion from 2040–2070), inland flooding ($42 billion/yr), sea level rise ($18 billion/yr to replace flooded property), and water shortages (around $3 billion a year) (see Table 6 for California below from Bedsworth et al. 2018). The California assessment notes that "many other important impacts have not been quantified, including public health and property damage from wildfires, impacts on human morbidity from high temperatures, impacts of drought on water quality, and impacts to habitat and other ecosystem services. All of these damages are likely to be costly".

TABLE 6 | ORDER OF MAGNITUDE ESTIMATION OF DIRECT ECONOMIC IMPACTS FROM CLIMATE CHANGE BY 2050.

EFFECT OF ACTIVITY	MAIN CLIMATE DRIVER	COST ($ billion/year)	COMMENTS
Human mortality*	High ambient temperatures	50	Premature annual mortality (Ostro et al., 2011) translated into monetary terms using a value of a statistical life of $7.5 million.
All sectors of the economy	Mega-flood** similar to the one that devastated California in 1861-1862	42	One recent study by Swain et al., (2018) suggests a substantial likelihood of these floods in the rest of this century
Replacement value of buildings (residential and commercial sector)	Permanent inundation	18	Assuming 50 cm (~20 in) of sea-level rise, which is in the upper range (~95th percentile) of potential sea-level rise outcomes by 2050 (Pierce et al., 2018). Costs obtained from https://www.usgs.gov/apps/heral accessed on July 7, 2018.
Water supply and agriculture	Potential effect of a long drought	> 3	Assuming reductions in precipitation from 5 to 30 percent from historical conditions. Actual impacts would be much higher than $3 billion because the economic models assume very efficient adaptation. (Herman et al, 2018; Medellín-Azuara et al., 2018).
Energy demand: residential sector	Increase temperatures	< 0.2	Increases in electricity demand ($0.65 billion) would be compensated by reductions of demand for space heating ($0.5 billion). (Auffhammer et al., 2018). Expected increases in energy efficiency will also lower costs even further.
Other impacts (e.g., human morbidity, loss of human lives and properties during wildfires)	Changes in temperature, aridity, wildfires, inland flooding, etc.		Unquantified or poorly quantified (see Appendix B).
Ecological impacts	Changes in temperature, aridity, wildfires, inland flooding, etc.		Unquantified. Some argue that it is impossible to estimate the value of ecosystems in monetary terms for both practical and ethical reasons. Others are working to quantify the value of ecosystem services.

See Appendix B for a more detailed table and documentation of assumptions.

* Implementation of adaptation measures (e.g., increased penetration and access of space cooling) could substantially reduce these impacts.

** Swain et al., 2018 is the only study suggesting an increased probability of a mega flood with a changing climate. Given the high costs associated with this event, it is listed in this table to highlight the importance of additional studies on this topic using different methods. The $42 billion cost is estimated taking into account the probability of this event in a 5 year period centered in 2050.

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United States House of Representatives Select Committee on the Climate Crisis

Hearing on April 30, 2019, "Solving the Climate Crisis: Drawing Down Carbon and Building Up the American Economy"

Questions for the Record

Christopher Guith, Acting President, Global Energy Institute, U.S. Chamber of Commerce

THE HONORABLE GARRET GRAVES

1. Has the Chamber's position on climate change changed?

The Chamber has long supported sensible action to address anthropogenic climate change, with special emphasis on the fundamental role technology, supported by sound, durable policies, will play in mitigating it and adapting to it. That has not changed. We welcome the renewed emphasis on bipartisan solutions that can preserve American jobs and economic growth, maintain the international competitiveness of our businesses and industries, increase energy access to the nearly one billion people living in energy poverty, and improve the environment.

America's business community is ready, willing, and able to provide the solutions that will continue to reduce emissions while growing the economy. Our companies and entrepreneurs will continue to lead by bringing innovation, technology, and ingenuity to this challenge, just as they have done with other environmental challenges. With a sensible policy environment that plays to America's strengths and business leadership, we can continue to make our economy cleaner and stronger by leveraging the America's edge in energy, technology, and innovation going forward. The Chamber looks forward to working with members on both sides of the aisle to fashion climate solutions that are sensible, effective, and durable.

2. It was mentioned that the NERA report the American Council on Capital Formation and the Global Energy Institute sponsored examining the costs of meeting the Obama Administration's pledge under the Paris Agreement has been "debunked." Could you respond to this statement.

The NERA report was a solid and in many respects groundbreaking piece of analytical work. First, the business community supports the Paris framework, and continues to do so. It should be noted that had the Obama Administration laid out a

plan to meet its Paris pledge and conducted an economic analysis of it, hiring NERA to do such an analysis would not have been necessary. Concerning the report itself, reproduced below is a response to critics of the report that GEI posted in June 2017 and that should put to rest any claims that it has been debunked:

June 3, 2017
Setting the Record Straight on the NERA Report
By Dan Byers & Stephen Eule

SUMMARY

Over the last few days, there has been a lot of attention given to a report that the Energy Institute co-sponsored that examined the costs of meeting the Obama Administration's Paris pledge. The report by NERA Economic Consulting, Impacts of Greenhouse Gas Regulations on the Industrial Sector, examines the costs of filling the gap between what President Obama committed to—a 26% to 28% reduction in net greenhouse gas emissions by 2025 compared to 2005—and the plans he proposed to accomplish it.

President Trump cited some of the results of the study. Some media outlets and others have mischaracterized the report and its findings. Here we set the record straight on two key critiques. (For more in-depth analysis read beyond this summary.)

The first erroneous claim is that the policies modeled by NERA were based on "worst-case assumptions" that would "inflate the cost of meeting U.S. targets under the Paris accord."

This is not true.

The NERA study generated five unique scenarios using realistic and reasonable cost estimates based on Department of Energy baseline forecasts—not the one scenario with "worst-case assumptions" as has been claimed. The data from the study cited by President Trump were from the scenario that most closely followed the Obama Administration's regulatory approach. In addition, other analyses—by Hillary Clinton's campaign and the Energy Information Administration, for example—show impacts of meeting the goal similar to the range of outcomes in the NERA study.

The second erroneous claim is that study does not count the economic benefits from constructing and operating new renewable generating facilities. This claim, too, is false.

The NERA model used in the study does NOT ignore positive economic contributions from renewable energy projects. It simulates ALL economic interactions in the U.S. economy, including the economic benefits from renewable energy projects. The model calculated benefits from the building and operating of renewable energy projects. However, in the model, these economic benefits were outweighed by increased costs.

The model design is discussed extensively in the report. It makes it clear that it captures all types of responses and benefits from the various regulatory decisions that would be made to meet the pledge.

The reason the study was conducted in the first place was to undertake the analysis the Obama Administration failed to do before and after it made its Paris pledge. It makes sense to at least understand what the impacts of that pledge would be and how it might be achieved. The report is transparent in its assumptions and its data, explains its methodologies, and provides multiple scenarios which take into account both the benefits and costs of meeting the pledge.

There will be considerable debate about the President's decision, but criticism of the NERA report is unwarranted.

We have addressed other critiques of the NERA report here <https://www.globalenergyinstitute.org/nrdc-swings-and-misses> and here <https://www.globalenergyinstitute.org/wri-also-swings-and-also-misses>, and readers interested in a more detailed response to the critiques describe above should see below.

DETAILED ANALYSIS

Claim One: The policies modeled by NERA were based on "worst-case assumptions" that would "inflate the cost of meeting U.S. targets under the Paris accord." This is false.

This argument isn't new—some environmental groups made it when the report was first released. While we've addressed it here and here, let's take another stab at it.

First and foremost, the NERA report didn't just look at one "worst case" scenario—it actually examined five, including one that set a price on carbon

as a way to achieve the emissions reduction the U.S. has committed to. All of those scenarios produced different results, which were included in the report.

The numbers cited by President Trump were specific to one particular scenario, which reflected the reflected the regulatory approach being taken by the Obama Administration and that most likely would have been taken by a Clinton Administration has Hillary Clinton won the election.

There is solid evidence to back this up. The Obama Administration's fiscal year 2015 budget request for the Environmental Protection Agency included funding to develop this scenario—new greenhouse gas regulations on industrial sectors. And in official meetings with stakeholders, the Obama Administration did not hide its intention to regulate industrial emissions. *InsideEPA* reported on White House meeting where, *"administration officials were candid in their plans to regulate manufacturing GHGs to address an emissions gap' between current and proposed climate rules and President Obama's INDC pledge to cut GHGs 26 to 28 percent from 2005 levels by 2025."*

While we're on the subject of assumptions, critics have also asserted that the NERA results are out of line with results from other analysts. That's not the case.

During the election, it turns out that the Clinton campaign undertook modeling to estimate the costs of closing the Paris gap. It set a greenhouse gas fee at $42 (2012$) per ton of carbon dioxide from energy use in 2017 and increased it by roughly 2% a year thereafter. This study found significant economic impacts: *"In our analysis, for example, a $42/ton GHG fee increases gasoline prices by roughly 40 cents per gallon on average between 2020 and 2030 and residential electricity prices by 2.6 cents per kWh, 12% and 21% above levels projected in the EIA's 2014 Annual Energy Outlook (AEO) respectively. Average household energy costs would increase by roughly $480 per year, or 10% relative to the levels projected in EIA's 2014 Outlook."*

The NERA results also are consistent with those from modelling runs performed by EIA under President Obama. Among the many side case modelling runs in the AEO 2016 was the "Industrial Efficiency High Incentives" side case, which EIA describes this way: "Uses a price on carbon dioxide emissions as a proxy for higher energy costs as a way to increase energy efficiency in all industries except refining. The carbon dioxide price is phased in gradually, starting in 2018, reaching $35.00 in 2023 (2015 dollars per metric ton), and increasing by 5% per year thereafter."

Why is this model run interesting? Because it produces cuts in economy-wide energy-related carbon dioxide emissions in 2025 of about 30% below the 2005 level, entirely consistent with President Obama's Paris economy-wide greenhouse gas pledge.

When compared to EIA reference case model run (without the Clean Power Plan), this scenario produces the following results (all dollar figures in 2015$):

- Change in GDP in 2025: −$269 billion Cumulative Change in GDP from 2018–2025: −1.92 trillion
- Change in Employment: Trough of −1.4 million in 2023 and −955,000 in 2025
- Change in Average Electricity Price in 2025: +19%
- Change in Cumulative Electricity Expenditures from 2018–2025: +$350 billion
- Change in Average Gasoline Price in 2025: +11%

As these other studies make plain, the NERA study we co-sponsored is not an outlier by any extent of the imagination.

Claim Two: The study guilty of not counting the economic benefits from constructing and operating new renewable generating facilities. This claim is false.

The NERA model used in the study simulates ALL economic interactions in the U.S. economy, including the economic benefits from renewable energy projects. The model calculated benefits from the building and operating of renewable energy projects, but in the model these were far outweighed by higher costs on producers, consumers, and the overall economy due to broader greenhouse gas regulations on other sectors.

The model design and description is detailed extensively in the report. One section notes the following: *"Throughout the time horizon of the module*

run, in order to meet any increase in electricity demand, increase in reserve margin requirements, and/or replacement of retired generation, the electric sector must build new generating capacity. Future environmental regulations, system constraints (e.g., reserve margin requirements), capital costs, and forecasted energy prices influence which technologies to build and where. For example, if a national RPS policy is to take effect, some share of new generating capacity will need to come from renewable power. On the other hand, if there is a policy to address emissions, it might elicit a response to retrofit existing fossil-fired units with pollution control technology or enhance existing coal-fired units to burn different types of coals, biomass, or natural gas. All of these policies may also affect retirement decisions. The NewERA electric sector module endogenously captures all of these different types of decisions." [Emphasis added]

So that criticism doesn't hold water, either.

3. Concerning H.R. 9, are the Nationally Determined Contributions other nations have offered up part of the Paris Agreement.

No. Parties to the Paris Agreement have a binding obligation to submit periodically Nationally Determined Contributions (NDC). The goals in the NDCs themselves, however, are not binding in any way, and they are not part of the Paris Agreement itself (unlike pledges under the Kyoto Protocol, for example, which were negotiated and appended to the treaty).

United States House of Representatives Select Committee on the Climate Crisis

Hearing on April 30, 2019, "Solving the Climate Crisis: Drawing Down Carbon and Building Up the American Economy"

Questions for the Record

Mr. David Foster, Distinguished Associate, Energy Futures Initiative

THE HONORABLE KATHY CASTOR

1. In your testimony, you said, "We need to accelerate our investments in energy efficiency with a special priority on those regions of the country negatively impacted by declining use of fossil fuel." Can you provide more detail on the types of energy efficiency investments we should make in these communities?

Fossil fuel production is concentrated in those states with readily accessible resources. Currently, 73% of all coal production jobs are located in just 10 states; 74% of all oil production jobs are also located in just 10 states; and 84% of all natural gas production jobs are similarly concentrated in 10 states. Compounding this problem is the fact that two states, Texas and Pennsylvania, are in the top ten in all three fossil fuel production jobs while eight others—West Virginia, Louisiana, Oklahoma, Illinois, Wyoming, Colorado, New Mexico, and California—are in the top 10 in two fossil fuel resources.

While jobs in oil and natural gas fuels production rose in 2018 by over 50,000 jobs and have increased significantly from a decade ago, the opposite is the case for coal fuels' production. As a result, the states and communities impacted by the loss of coal fuels' jobs, along with those states and communities with the most coal power generation jobs, should receive special attention in economic development resilience planning. There are four ways that energy efficiency investments can benefit these highly impacted communities.

The four response areas are energy infrastructure, the industrial sector, commercial buildings, and residential buildings. Energy efficiency investments are needed to meet carbon emissions reduction targets in every part of the country and in each of these sectors. However, by targeting those communities whose employment has been adversely impacted by the decline in coal production first, jobs can be provided in labor markets already suffering from higher than average unemployment. Given the demonstrated hiring crisis in energy efficiency (especially in its largest sector—construction—where a majority of employers reported that it was very difficult to hire new employees in 2018), a focus on introducing energy efficiency technologies into these communities is a sensible response to worker dislocation.

A four-pronged energy efficiency initiative in these communities and regions provides the added benefit of reducing residential consumer energy costs and making businesses and real estate more economically competitive.

In the first edition of the Quadrennial Energy Review focused on Transmission, Storage and Distribution and released in April, 2015, the Department of Energy recommended that DOE should,

> Provide state financial assistance to promote and integrate TS&D infrastructure investment plans for electricity reliability, affordability, efficiency, lower carbon generation, and environmental protection. In making awards under this program, DOE should require cooperation within the planning process of energy offices, public utility commissions, and environmental regulators within each state; with their counterparts in other states; and with infrastructure owners and operators and other entities responsible for maintaining the reliability of the bulk power system.

Implementation of such a program, focusing first on Appalachia and other coal-impacted communities, would provide immediate economic support, job creation, and greater efficiency and resilience.

In many of the communities that were originally built around the availability of coal resources, manufacturing also plays a more significant role in local economies. A focus on industrial energy efficiency would preserve the competitiveness of the existing manufacturing ecosystem while also creating demand for energy efficiency industrial products, particularly electrical motors, one of the largest consumers of energy in manufacturing. Many of the top 10 coal producing states—PA, OH, IL, IN, KY, and WV—have significant manufacturing employment in both energy intensive industries such as steel and aluminum, but also in the production of energy efficiency products. These kinds of industrial energy efficiency investments, thus, have the twin benefit of reducing costs while increasing product demand. Programs such as DOE's Industrial Assessment Centers which provide energy efficiency assessments to small and medium sized manufacturers could be expanded in these communities.

Commercial and residential energy efficiency building retrofit programs could also be significantly expanded in the target areas, financed through federally guaranteed revolving loan programs with the loans paid back through energy savings.

This kind of focused investment on energy efficiency in multiple sectors of the economy provides affected communities with the skills training needed for the jobs of the future. Increased deployment of energy efficiency technologies is going to be needed for at least the next 30 years to meet carbon reduction targets. Perfecting the model for concentrated investment in energy efficiency in coal communities today will provide a model for similar investments in other geographies where unemployment levels are endemically high.

2. In your testimony, you said: "Carbon performance should be a universal procurement standard for government spending in the U.S., similar to what California recently did with its Buy Clean standard." Can you provide more detail on what a federal "buy clean" procurement standard would entail and how it would work?

The California legislation amended state contracting provisions as follows, "The Buy Clean California Act, (Public Contract Code § 3500–3505), states the Department of General Services (DGS) is required to establish and publish the maximum acceptable Global Warming Potential (GWP). It targets embedded carbon emissions of structural steel (hot-rolled sections, hollow structural sections, and plate), carbon steel rebar, flat glass, and mineral wool board insulation. These materials must have a GWP that does not exceed the limit set by DGS." *https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act.*

Industrial emissions make up approximately 21% of all global greenhouse gas emissions with ⅔ of industrial energy consumption coming from five key sectors, commonly known as "energy intensive, trade exposed" industries or EITE's. A federal "buy clean" procurement standard would require that all prospective bidders for federal government projects provide a life cycle assessment of the direct and indirect emissions associated with all materials proposed for use in an awarded contract that fall within the definition of EITE products. By limiting the coverage of the "buy clean" standard to those products that produce the majority of industrial greenhouse gas emissions, the standard will achieve maximum effectiveness with a minimum of regulatory oversight.

A "buy clean" standard would play a dual role, reinforcing carbon reduction policies in the industrial sector, while, at the same time, promoting the economic competitiveness of high performing, energy efficient U.S. businesses which are already among the lowest emitting producers of energy intensive products in the world. That is why a broad coalition of California stakeholders supported passage of this legislation including environmental organizations, unions like the United Steelworkers, and California steel producers such as Gerdau Steel.

3. In your written testimony, you say: "sequencing and timing of how we solve a problem can ultimately determine the support it achieves from our fellow Americans." As we look how to decarbonize the electricity sector, how would you recommend we sequence policy implementation to maximize emissions reduction and public support?

There are several policies that I think would increase public support for decarbonizing the electricity sector. The first would be the enactment of a federal clean energy standard (CES) such as was recently introduced by Senator Smith (MN) and Representative Luján (NM). A CES that uniformly provides incentives for carbon reductions, even partial ones such as achieved by high efficiency natural gas or carbon capture sequestration technologies, removes any doubt from the public mind about the actual goal of decarbonization. It's not about rewarding one technology over another such as wind or solar; it's about finding the most cost efficient, secure, and reliable approach to decarbonizing over a 30 year glide path.

Second, I would recommend a national initiative to modernize the electrical grid to achieve significant efficiencies by reducing current power loss. Such an initiative, focused first on those regions and states suffering from job loss in coal communities, would demonstrate the federal government's commitment to use our energy transition to promote economic opportunity, job creation, and skills' training for high unemployment regions. Initial funding for such an infrastructure program could come from the U.S. Department of Energy's Loan Program Office. See the analysis on this issue from the Energy Futures Initiative at: *https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5b4e7494758d463f2a81294a/1531868312531/Leveraging+the+DOE+Loan+Program_SG_v4_TB+CLEAN.pdf.*

Third, I would recommend a special initiative on reducing industrial emissions and building domestic clean energy supply chains to demonstrate that federal policy is focused on making the U.S. the global leader in clean energy manufacturing. Components of such a policy would include restoring the 48C Advanced Energy Manufacturing Tax Credit, passing a "buy clean" federal procurement policy, establishing an industrial energy efficiency tax credit, and integrating carbon-based border adjustments for EITE's. Implementation of an EITE border adjustment policy could be done as part of the current USMCA or the original NAFTA and would provide an initial global mechanism for encouraging reductions in industrial emissions while also rewarding existing American companies in these critical sectors—iron and steel, aluminum, pulp and paper, chemicals, cement, brick, and glass—for their relatively high environmental performance.

Manufacturers and their employees have played a critical role in resistance to decarbonizing the electrical sector out of concern for competitiveness in global markets. Addressing these concerns directly by providing economic incentives to decarbonize manufacturing would turn this resistance into support.

Fourth, I would recommend making energy efficiency investments, particularly in negatively impacted coal communities and in high unemployment pockets whether in rural or urban areas, the center piece of a national effort to reduce carbon emissions by the creation of energy efficiency jobs. Since this sector exists in virtually every county in America and has already produced over 2.3 million jobs, this positive focus on new job creation presents the public with a powerful reason to support the transition to a low carbon economy. In addition, the majority of energy efficiency jobs are in construction, and pay better than similar jobs in the economy at large because of higher unionization rates and skills' requirements. They also rely on skills that are readily transferable to other sectors of the economy. There are many local examples of how to fund energy efficiency investments such as green banks, revolving loan funds, etc., but the federal government should adopt a complete menu of tax credits, supports for utility-funded programs, and grant programs to bring energy efficiency investments to scale.

Finally, I would recommend reauthorizing the Energy and Advanced Manufacturing Workforce Initiative (EAMWI) started by the U.S. Department of Energy in 2016 to coordinate the workforce development efforts of the Departments of Energy, Labor, Commerce, Education, Defense and the National Science Foundation. EAMWI activities would insure maximum success in energy efficiency job training curriculum development, realization of job training activities in the field, and successful deployment of new energy efficiency and energy technologies.

4. In your written testimony, you say: "We need to focus on the manufacturing supply chains that our new energy technologies are creating. Nothing is more frustrating than looking back over the years of American technological innovation and recording the history of American applied research being handed off to other countries for commercialization." What can Congress do to ensure U.S. workers manufacture the components needed to build a cleaner energy economy?

There are several pieces of legislation that Congress could consider to address this issue. First would be the restoration of the 48C Advanced Energy Manufacturing Tax Credit which was significantly oversubscribed when it was first introduced and successfully created tens of thousands of new jobs before it expired.

Second would be the creation of a collaboration between the Advanced Manufacturing Office (AMO) of the DOE, National Institute of Standards and Technology (NIST), and the Manufacturing Extension Partnership (MEP) that would be required to perform periodic supply chain analyses of all new energy technologies, prepare qualification assessments of OEM's for parts production, and deliver workshops on the qualification process and standards for small manufacturers at the state level.

Third would be the creation of domestic content standards for the production of critical energy equipment similar to the rules that exist for other products of national security importance under the Buy America Act.

Fourth would be the restoration of funding for Mission Innovation, the pledge to double government investments in clean energy research and development in five years, led by the U.S. and announced at the time of the Paris climate agreement. The maintenance of high levels of R&D funding is critical to a healthy manufacturing economy.

United States House of Representatives Select Committee on the Climate Crisis

Hearing on April 30, 2019, "Solving the Climate Crisis: Drawing Down Carbon and Building Up the American Economy"

Questions for the Record

Mr. Hal Harvey, CEO, Energy Innovation LLC

DEAR REPRESENTATIVE CASTOR: I appreciate the chance to respond to questions from yourself and Congressman Ben Ray Luján. Your questions and our responses follow, but please note that we would be happy to elaborate on any point, or consider other issues.

THE HONORABLE KATHY CASTOR

1. In your written testimony, you say the following about cleaning up the electricity sector: "We have the technology (and it's increasingly cheaper to deploy clean rather than polluting power plants), we have the know-how, we just need to get this moving—and quickly." What are the primary barriers standing in the way of faster deployment of clean energy technology?

Technology and cost are no longer major barriers to deep electricity sector decarbonization—institutions and information are. Conventional wisdom that wind and solar require 100 percent redundancy from dispatchable power plants is not accurate. Numerous studies including some by federal agencies [1] and our national laboratories [2] show we can reliably operate very high penetrations of renewable electricity using today's technologies at a similar cost as today's electricity system. Further advancements in energy storage and renewable energy technologies, coupled with digitized devices able to respond to real-time grid needs, hold tremendous promise to further reduce costs as we decarbonize the electric grid. With such technological tailwinds, we now must turn our attention to overcoming four barriers: slow infrastructure development, incumbents preventing uneconomic fossil retirement, market barriers to renewable energy, and fossil fuel-dependent communities impacted by transition.

Our grid infrastructure has been slow to adapt to the fundamentally new characteristics of clean electricity technologies. Renewable energy is always available somewhere, and long-distance transmission lines enable excess in one part of the country to compensate for deficits elsewhere. Despite clear consumer benefits from expanding transmission lines to access low-cost renewables and sharing resources over large areas, developing new long-distance transmission lines often takes more than 10 years, and many promising projects never materialize.[3] At the local distribution level, demand-side resources like storage are unable to participate meaningfully in grid management, restricting a crucial source of flexibility [4] to support

[1] https://research.noaa.gov/article/ArtMID/587/ArticleID/542/Rapid-affordable-energy-transformation-possible.

[2] https://www.nrel.gov/analysis/re-futures.html, https://www.nrel.gov/docs/fy18osti/71465.pdf.

[3] See answer to Question three below for ideas on how to jumpstart transmission development.

[4] https://energyinnovation.org/wp-content/uploads/2018/07/OrvisAggarwal-WholesaleMarketsFlexibility-June2018.pdf.

renewable energy. New data management systems and advanced rate designs are needed, yet monopoly distribution utilities lack proper incentives to innovate and improve efficiency under conventional cost-based revenue regulation.

Legacy rules, procurement, and market products also favor incumbent fossil fuel-based technologies and make it more challenging for new technologies to participate in energy markets. Uneconomic fossil generators are not retiring as fast as they should, as backward-looking market designs (described in more detail in the answer to Question Two below) keep inefficient coal and natural gas units online. At the state level, utilities owning these assets resist retirement, and regulators lack the financial tools to accelerate retirement of uneconomic coal assets without harming customers [5].

Grid operators including utilities stack the deck against new renewables. In electricity markets, renewable energy, demand-side resources, and storage face significant barriers—in the form of obsolete rules—to participation and often cannot provide their full range of value to the market. In monopoly jurisdictions, utilities use outdated cost assumptions and trumped-up integration cost estimates to prevent competition from renewables in procurement processes. As evidence of the market potential, 280 gigawatts of wind and solar projects are stuck in queues for interconnection wholesale markets alone, enough to *treble* U.S. renewable generation capacity. Developers and financiers are ready, but cannot access the market.

A rapid renewable energy transition risks leaving behind entire communities dependent on coal mining and fossil power plants. These communities often rely on mining and power plants for both jobs and local tax revenue to support social services. But viable local clean alternatives exist—local wind or solar could replace three quarters of existing U.S. coal capacity at a lower cost to consumers,[6] and the federal government could support this just transition with financing and worker retraining programs in partnership with local utilities.

2. In your testimony, you say: "The first policy I would recommend is to require that the Federal Energy Regulatory Commission be a merit driven, technology neutral, adjudicatory body required to run the power system at the lowest cost." Would Congress need to make changes to authorizing statutes to implement the technology neutral FERC idea? Describe.

Congress does not need to make changes to the Federal Power Act, which provides FERC's legal authority, but it does need to insist that FERC actually satisfies its obligations to ensure just and reasonable rates and avoid undue discrimination. In other words, Congress needs to hold FERC accountable to its obligation to be merit-driven and technology neutral while ensuring fair prices and reliability. As Commissioner Glick recently pointed out,[7] FERC has historically interpreted its just and reasonable rate authority and obligation to avoid undue discrimination as requiring technology neutrality.

FERC precedent and court interpretations clearly maintain that FERC's duty is to create a level playing field for all grid resources to compete on their technological and cost merits. Of course, if Congress wants to emphasize a certain aspect of that duty, for example, that FERC require grid operators to take proactive steps to develop (as transmission assets) and deploy (as grid services) distributed energy resources when they are the lowest cost option, additional legislation could accelerate those changes.

One recent FERC decision approving a pernicious policy in two FERC-regulated wholesale electricity markets [8] punishes states taking action on greenhouse gas emissions. These markets impose a Minimum Offer Price Rule (MOPR), the original intent of which is to mitigate against buyer-side market power, on renewable power plants receiving state support through a renewable portfolio standard (RPS). In effect, the MOPR requires renewables to bid in at an administratively determined price greater than the actual cost of running these plants, which is zero. This in turn raises the wholesale electricity price and supports fossil-fueled plants which otherwise would retire.

The MOPR undermines state choice—states are being forced to pay for fossil-fueled power plants that constituents don't want and market operators don't need for reliability. Congress should clarify that the MOPR should not be applied to resources receiving state policy support.

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[5] https://energyinnovation.org/publication/managing-the-utility-financial-transition-from-coal-to-clean-2/.

[6] https://energyinnovation.org/publication/the-coal-cost-crossover/.

[7] page 15 https://www.eba-net.org/assets/1/6/%5BGlick_and_Christiansen%5D%5BFinal%5D.pdf.

[8] PJM Interconnection and ISO-New England.

The root of these backward-looking market design policies is institutional lag behind the economic and political realities driving the U.S. toward more renewable energy. Markets using the MOPR still see renewables as undermining the integrity of markets, rather than redesigning the markets to fairly accommodate these resources. Reliability services markets are based upon, such as peak capacity needs, respond to the existing system's performance attributes. MOPR ensures that fossil resources receive revenues through capacity markets, even when a high renewables system would not need that same service. As renewable energy output varies with weather, complementary resources can and should provide flexibility, especially the underused resources of responsive demand, efficiency, and storage. Rather than defining new services to accommodate state constituents' preferences for low-cost renewables, market operators have kept one foot in the past, and FERC has been loath to correct them.

Serious technological changes are hitting the electricity grid, but the concomitant changes in market incentives and rules are lagging behind, as are the mechanisms to allow more demand side participation. FERC and the ISOs/RTOs wholesale electricity markets have done little to accelerate this transformation, instead in many cases setting rules prejudiced against clean energy. As new technologies come online at lower prices and higher volumes, Congress should consider examining whether existing wholesale electricity market structures are equipped to handle today's technology.

3. During Q&A, you stated the following in response to a question from Rep. McEachin: "One element I would propose is expanding transmission lines across the country to help balance renewables and balance the whole system. In fact, I think we should look at ways to streamline permitting. I advocate pre-zoning into red, yellow, and green zones, where red, you are just not going to build anything; green, you get a permit in 90 days if you meet the proper specs; and yellow is like everything today, it is an all-out war. So we just need to clean that up and save a lot of time and a lot of trouble." Can you provide more detail on how to design a red/yellow/green zoning process for transmission?

The National Renewable Energy Laboratory (NREL) recently completed a study[9] of the value of interconnecting the entire country with high-voltage direct current (HVDC) transmission, modern transmission technology widely used by China to build out and improve the efficiency of its grid. NREL's study calculated up to a 3-to-1 benefit to cost ratio from a transmission overlay connecting East and West so that clean energy can reach cities and factories anywhere across the nation.[10] A similar study from the National Oceanic and Atmospheric Administration (NOAA) found that reducing carbon emissions 80 percent using today's technologies was possible at negligible incremental cost if we build out a national HVDC grid to support renewable development and integration.[11]

In the U.S., a HVDC transmission overlay linking the country's three electric grids and remote high-quality wind and solar resources with demand centers would reduce overall costs to consumers, open up massive opportunities for new renewable resources to access the market, and provide grid operators with additional tools to balance an increasingly variable electricity mix.

Reducing permitting and siting problems by pre-screening federal and state lands for transmission corridor suitability is crucial to enabling this transmission overlay. This is already ongoing in the Western U.S., through the federal West-wide Energy Corridors[12] planning process, and should be expanded to the rest of the country. The planning process identifies continuous strips of federal land across jurisdictional boundaries suitable for transmission development. Robust stakeholder engagement minimizes environmental, cultural, and other stakeholder conflicts. Eventually, this process will streamline federal siting, review, and permitting processes for transmission developers. Parallel efforts to engage with private landowners crucial to completing many of the corridors will increase the likelihood of success.

Data is also key to pre-screening transmission. The Western Electricity Coordination Council has developed the Environment Data Viewer,[13] a tool that should be expanded for the rest of the U.S. to enable smart infrastructure development. The tool uses Geographic Information Systems (GIS) data for different land conflicts, en-

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[9] https://cleanenergygrid.org/wp-content/uploads/2018/08/NREL-seams-transgridx-2018.pdf.

[10] Unfortunately, DOE has refused to release the study. https://cleanenergygrid.org/interconnections-seam-study/.

[11] https://research.noaa.gov/article/ArtMID/587/ArticleID/542/Rapid-affordable-energy-transformation-possible.

[12] http://corridoreis.anl.gov/.

[13] https://ecosystems.azurewebsites.net/WECC/Environmental/.

abling users to create maps of low-conflict land. For example, lowest conflict existing rights of way are green; low-conflict undeveloped land is yellow; and land with explicit environmental, infrastructure, or cultural conflicts ranges from orange to red. The tool uses professional judgment of transmission planners, Bureau of Land Management and U.S. Forest Service, environmental leaders, and even archaeologists to build the tool's classifications .

Some obvious "green" zones exist—along existing transmission corridors or highways, for example. These should be promptly identified and so-designated. Some places should be labelled "red," such as wilderness study areas, or areas with ecologically important biota. Making these strictly off limits can reduce time and money spent on fruitless pursuits.

Note that this recommendation does not contemplate relaxing environmental standards, but instead doing the work to designate these three classes in advance to reduce uncertainty, time, and money.

Besides providing corridors and data, the federal government can also facilitate inter-state cooperation on transmission development. Though all consumers should benefit from a more robust HVDC transmission network, these benefits are often not distributed equally among states. The largest beneficiaries of HVDC transmission are likely the producer state and the load center on the other end of the line, making states between the two reticent to accept transmission development without compensation. The federal government can facilitate dialogue between states involved.

4. During the hearing, Rep. Palmer stated the following: "In California right now, there is a lawsuit that has been filed by minority group against the California Air Resources Board, because of the harm that it is doing to low income people. Since the effective date of California's greenhouse gas reduction law, the Global Warming Solutions Act, 41 states have reduced their per capita greenhouse gas emission more than California, but it had enormous negative impact on the people in California. So, I think, we have got to look at this in the broader spectrum of how this affects everybody, and the U.S. obviously I think we continue the best in the technologies to reduce our carbon emissions." As an energy expert living and working in California, what is your response to this statement?

As the world's fifth largest economy, California is a global leader on climate change and a model of successful greenhouse gas reduction policy. As of 2016, only New York and the District of Columbia have lower per capita energy-related carbon dioxide emissions than California.[14] Rep. Palmer cites data related to per capita emissions reductions that ignores California's thirty-plus years of environmental leadership before enacting the Global Warming Solutions Act. In 2006 when the bill passed, California was already a national leader in renewable energy and used virtually no coal-fired power, the reduction of which accounts for the vast majority of U.S. emissions reductions since 2006. California has much work left to reduce emissions to meet its goals, but is well on its way to creating an equitable, affordable, low-carbon future.

Low-income community opposition to California's Global Warming Solutions Act is vastly overstated. The lawsuit takes issue with proposed measures in a planning document from the California Air Resources Board specifying measures that can reduce greenhouse gas emission in line with the state law—40 percent below 1990 levels by 2030. The group backing the lawsuit, the Two Hundred, is represented by a law firm whose work has focused on fighting environmental protections in California for the last 30 years. Masquerading as a civil right issue, this lawsuit creates a pretext for removing the very environmental protections low-income residents depend on.

Recent polling[15] indicates low-income residents are more likely to support cap-and-trade than not. Disadvantaged communities and the organizations representing them recognize that climate change and pollution pose a real threat to the lives and economic security of low-income communities, and California has built vital protections for our communities into our climate laws. That's why dozens of disadvantaged community representatives support California's climate change policies and work constantly to ensure that they address poverty and pollution at the same time.

Of course, the revenue stream that pays for these programs is California's cap-and-trade program, which some have argued has a negative impact on the very same priority populations where climate investments are being made. The latest

[14] https://www.eia.gov/environment/emissions/state/analysis/pdf/stateanalysis.pdf at page 4.

[15] 44 percent of California residents with incomes under $40,000 favor cap-and-trade, while 39 percent oppose it. https://www.ppic.org/wp-content/uploads/ppic-statewide-survey-july-2018.pdf at 21.

data show $1.9 billion (more than 57 percent) of all implemented dollars raised by cap-and-trade are benefiting state-identified disadvantaged communities and low-income communities.[16] These investments are creating new affordable housing, improving accessible and affordable mobility, lowering energy bills, and creating new jobs, while also reducing greenhouse gases. Legislation established parallel programs to improve air quality in historically disadvantaged communities[17] and study low-income barriers to adopting clean energy technologies.[18]

5. During the hearing, members raised Chinese carbon pollution levels on numerous occasions. China's emissions now, and their future trajectory, are critical to addressing the climate crisis. Given your experience working in China, is the Chinese government implementing policies that will curb and ultimately reduce Chinese carbon pollution? Please explain.

It is true that without continued heroic public investment from the Chinese government, the world will fail to meet international emissions reduction goals necessary to limit warming to safe levels. It is also true that China has experienced rapid economic growth dependent on burning coal for industrial processes and electricity, resulting in citizens with higher incomes who now drive gasoline-powered cars. One cannot be sanguine or naïve about the environmental problems China faces, nor the vast Chinese contribution to climate change.

But in many ways, China's efforts to combat climate change have dwarfed those of the U.S. Despite its rapid rise to the world's largest greenhouse gas emitter, the Chinese government has systematically implemented policies to curb its greenhouse gas pollution for more than a decade, and remains committed to doing so in the future.

The Chinese government began including explicit climate change targets in its Five-Year Plan (FYP) in 2011. China's initial greenhouse gas reduction goals were aimed at reducing carbon intensity (carbon per unit of GDP). By 2017 China had cut carbon intensity 46 percent from 2005 levels, honoring its voluntary international commitment to reduce carbon intensity 40 to 45 percent from the 2005 level by 2020—three years ahead of schedule. Under the Paris Accord, China agreed to further reductions of carbon intensity 60–65 percent below 2005 levels by 2030, and will make "best efforts" to peak carbon emissions by or before 2030.

Through ambitious policy and public investment, China is now the world leader in two key clean energy technologies—renewable electricity and electric vehicles (EVs). Almost 30 percent of the world's renewable power capacity is in China, and in 2017, China added almost half the world's renewable power capacity. In China's 13th Five-Year Renewable Energy Development Plan, the government announced $373 billion in total renewable energy investment by 2020. This historic renewables investment played an outsized role in driving down the global solar module costs 90 percent since 2008.

China is also responsible for more EV sales annually than the rest of the world combined, and boasts the only city in the world with all-electric bus and taxi fleets: Shenzhen. BYD, the international leader in electric bus manufacturing, trails only Tesla in EV sales. As the world economy continues toward low-carbon development, China's industries are well positioned to take advantage.

China is evolving its command and control economic and emissions policy centered on mandates and subsidies into more sophisticated market approaches, starting with the world's largest carbon market, which will launch later this year (2019). Its current first phase only covers power generation accounting for some than 3.5 gigatons of annual carbon dioxide emissions, more than half of U.S. total annual emissions. The Chinese government plans to expand the market to cover other energy-intensive sectors.

Despite these policies, without more action China's emissions will continue to rise. Chinese climate goals are deeply influenced by international norms and leadership by other nations, and the loss of U.S. leadership in controlling greenhouse gases is definitely softening China's ambition. China begins designing new policies first by learning the best practices of other countries, often seeking to emulate innovative U.S. market design. U.S. leadership on low-carbon technology development and emissions reduction goals provides strong motivation for the Chinese government to continuously push for more aggressive goals.

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[16] https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/2019_cci_annual_report.pdf?_ga=2.14451895. 1868598449.1553707432092139052204.1553538057 at viii.

[17] AB 617 is the most recent effort by the state to improve air quality, particularly in EJ communities. The law is in the early stages of implementation but it was achieved due to a high level of engagement by priority communities on the issue of air pollution.

[18] SB 350.

THE HONORABLE BEN RAY LUJÁN

1a. How does a Clean Energy Standard, such as the Clean Energy Standard Act of 2019, put the United States on a trajectory towards producing electricity with net-zero carbon emissions by mid-century?

A clean energy standard (CES) such as the CESA of 2019 is an excellent way to decarbonize the power sector. The CESA of 2019 is a particularly good example of a CES, in that it allows for all types of clean energy technologies, and sets long-term targets with continuous improvement along the way, which will drive and sustain innovation. Such a bill would help rapidly decarbonize the power sector, and would incentivize clean energy companies to accelerate research and development, to meet a clear and aggressive long-term target.

By including all zero-carbon technologies, a CES provides a high degree of flexibility that helps decarbonize the power sector at the lowest cost. Additionally, it is already cheaper [1] in much of the country to build and run new clean energy than to simply pay for the operating costs of fossil plants, so a CES would actually help lower costs—right from the start.

An initial analysis of the bill using the Energy Policy Simulator (EPS) [2]—assuming the share of clean electricity increases linearly to reach 90 percent in 2040, then pushes toward 100 percent by 2050—suggests the CESA of 2019 would reduce power sector emissions from 2005 levels by about 75 percent in 2035. By 2030, according to the EPS, this CES would save around 20,000 lives due to cleaner air. By 2040, that number rises to about 38,000; by 2050, it reaches about 70,000.

1b. How would it stimulate good, well-paying jobs? How can a clean energy standard help to promote U.S. technological leadership and R&D efforts and how would leading on this the climate benefit domestic businesses?

The renewable energy industry has become a major U.S. employer. E2's recent Clean Jobs America report [3] found nearly 3.3 million Americans working in clean energy—outnumbering fossil fuel workers by 3-to-1. Nearly 335,000 people work in the solar industry and more than 111,000 work in the wind industry, compared to 211,000 working in fossil fuel extraction, of which only 50,000 are coal miners. Clean energy employment grew 3.6 percent in 2018, adding 110,000 net new jobs (4.2 percent of all jobs added nationally [4] in 2018), employers expect 6 percent job growth in 2019.

Clean energy jobs offer higher wages than the national average, and are widely available to workers without college degrees, according to new Brookings Institution research.[5] Landing a clean energy job can equal an 8–19 percent increase in income, and 45 percent of all workers in clean energy production (e.g. electricians, installers, repairers, and power plant operators) have only a high school diploma, while still receiving higher wages than similarly educated peers in other industries.

E2 reports the fastest-growing jobs across 12 states were in renewable energy during 2018, and the U.S. Bureau of Labor Statistics already forecasts [6] the country's two fastest-growing jobs through 2026 will be solar installer (105% growth) and wind technician (96% growth).[7] While we have no jobs estimate from this CES, it is reasonable to expect significant acceleration of these already encouraging trends, since the CES requires more than doubling current annual installations of wind and solar. Because the best wind and solar resources are available in the Great Plains, Southeast, and Southwest, opportunities abound for economic development in rural as well as urban areas.

1c. What other policies would complement a clean energy standard?

Congress should focus on three policy areas to enable a cheaper, faster clean electricity transition: Maximize existing transmission while streamlining future development, spur investment in flexible zero-carbon resources, and invest in building and end-use efficiency and electrification.

Maximize existing transmission while streamlining future development—Transmission is the platform that allows our nation's electricity system to function. As renewables provide increasing amounts of electricity in the U.S., we need to move it from the places with the greatest sun and wind resources to the places where peo-

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[1] https://energyinnovation.org/wp-content/uploads/2019/04/Coal-Cost-Crossover_Energy-Innovation_VCE_FINAL2.pdf.

[2] https://us.energypolicy.solutions/.

[3] https://www.e2.org/wp-content/uploads/2019/03/E2-2019-Clean-Jobs-America.pdf.

[4] https://www.whitehouse.gov/articles/2018-ends-312000-jobs-created-december-strong-year-job-market/.

[5] https://www.brookings.edu/research/advancing-inclusion-through-clean-energy-jobs/.

[6] https://www.bls.gov/ooh/fastest-growing.htm.

[7] https://www.bls.gov/ooh/fastest-growing.htm.

ple and businesses need to use it. We can do that by getting more out of our existing system,[8] and by adding new lines. The federal government could build on the National Interest Electric Transmission Corridors[9] to overlay priorities for greenhouse gas reduction goals, reforming and aligning transmission incentives with greenhouse gas objectives.[10] The federal government could then partner with states to increase capacity on existing rights of way, as well as build new lines. President Lyndon Johnson provided a model for this in the 1960s with the build-out of the Pacific Intertie.[11] Texas also provides a model—pre-approving and building out transmission to "Competitive Renewable Energy Zones," where clean energy resources are abundant. Market mechanisms can then be used to select the lowest cost projects to build clean power in those zones.

Spur investment in flexible zero-carbon resources and get more out of existing assets—Solar and wind power are the cheapest new zero-carbon generation sources today, but their production varies with the availability of sunlight and wind, so they require a more flexible power system to realize their value as power system decarbonizers. Fortunately, many options are already available to draw additional flexibility out of the power system, including improved grid and transmission operations. Grid flexibility can also come from physical assets, such as batteries and fast-ramping natural gas plants, better co-optimization power supply and power demand.[12] Congress incentivizes the investment in storage and demand response needed to balance a high-renewables grid, while also leveraging the national labs to partner with system operators to integrate better weather forecasting and market optimization software.

Invest in building and end-use efficiency and electrification—Using electricity more efficiently is a key policy for reducing the overall cost of a national CES. Because the majority of U.S. buildings standing today will still be standing in 2050, Congress must find ways to incentivize whole-building efficiency retrofits. To reduce overall costs and leverage the clean grid to decarbonize building heating, retrofits should combine appliance electrification and on-site clean power generation (e.g., rooftop solar), if practical and applicable.

A program with financial incentives including low-interest loans,[13] on-bill financing,[14] property tax financing,[15] and cash rebates at the point of equipment sale[16] for building decarbonization retrofitting could improve economics and stimulate investment. Programs should also encourage pay-for-performance, increasing the incentive for efficiency measures that reduce grid costs.[17] Incentives should cover electrification for the big end-uses—building heat, water heat, and clothes drying, while implementing appliance standards that ensure maximum efficiency and customer savings.

2. Would a low-carbon grid be as reliable and resilient as a predominately fossil fuel driven grid? Please explain.

Cleaning up the electricity supply brings different but manageable resilience and reliability problems. To reduce outages and improve security, policymakers should focus on the main causes of outages—the aging and vulnerable transmission and distribution systems.

A more distributed and decentralized grid relying on local solar and storage can be more resilient to centralized threats. Relying on smaller, uncorrelated power generators over a larger footprint improves reliability. At the same time, widening grid balancing areas and strengthening interregional transmission connections also reduce the risk associated with single generator or transmission failures.

With respect to a low-carbon power generation mix, the transition from fuel-based power to higher shares of renewable energy affects bulk power system reliability and resilience in a blend of both positive and negative ways.

For human-caused events, such as cyber or physical attacks, renewables can help to reduce fuel supply risk. Coal relies on rail delivery, which is subject to physical attacks, since roughly 40 percent of U.S. coal comes from Wyoming's Powder River

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[8] Dynamic line rating gets more out of the system than existing practices in much of the country (for more, see https://issues.nawindpower.com/article/using-grid-weve-got). Where needed, we can beef up transmission capacity on existing rights of way.

[9] https://www.energy.gov/sites/prod/files/edg/media/NIETC_Fact_Sheet.pdf.

[10] See also transmission answer for Rep. Castor.

[11] http://www.orkas.com/the-future-of-electric-transmission/.

[12] https://energyinnovation.org/wp-content/uploads/2017/10/A-Roadmap-For-Finding-Flexibility-In-Wholesale-Power-Markets.pdf.

[13] https://www.energy.gov/savings/low-interest-energy-loan-programs.

[14] https://aceee.org/blog/2019/04/bill-financing-gains-ground-faces.

[15] https://www.energy.gov/eere/slsc/property-assessed-clean-energy-programs.

[16] https://www.smud.org/en/Rebates-and-Savings-Tips/Improve-Home-Efficiency.

[17] https://www.brookings.edu/research/advancing-inclusion-through-clean-energy-jobs/.

Basin, and nearly all via the 103-mile Joint Line rail corridor.[18] And natural gas pipelines are vulnerable to cyber and physical attacks.[19] As demonstrated during the recent polar vortexes, coal piles on-hand can freeze,[20], and co-dependence on natural gas for heating and generation during extreme cold can threaten resource availability. Prolonged heat waves can leave nuclear unusable [21] if cooling water is too hot.

But renewable energy sources are not automatically resilient. A robust grid requires strategies to deal with natural events, such as adverse weather. Hydroelectric generation is drought-vulnerable, while cloud cover from intense storms and hurricanes can threaten solar availability. Extreme winds may force partial wind curtailment for short periods of time.

Resilience can be achieved first by strengthening the distribution system for utilities—which causes by far the most power interruptions.[22] Second, by making the transmission grid more "islandable," meaning that grids can automatically isolate blackouts in small areas so they do not cascade through the system. Third, having a heterogenous set of clean energy sources and geographically dispersed supplies provides insurance against failures. Smart strategies to manage demand via demand response technologies gives many more options to grid operators. And of course, energy efficiency dramatically reduces stresses on the grid, and allows for more "ride through" in the case of disruption.

The upshot is that with smart operations and policy, the grid can be made more resilient and more reliable, even as we move to clean energy at scale.

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[18] https://www.nap.edu/read/11977/chapter/7.

[19] http://docs.house.gov/meetings/HM/HM07/20160419/104773/HHRG-114-HM07-Bio-ParfomakP-20160419.pdf.

[20] https://www.greentechmedia.com/articles/read/as-extreme-weather-forces-coal-to-falter-where-will-resilience-come-from#gs.frgowa.

[21] http://www.unisdr.org/files/1145_ewheatwave.en.pdf.

[22] https://rhg.com/research/the-real-electricity-reliability-crisis-doe-nopr/.