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OPPORTUNITIES FOR ENERGY INNOVATION AND OTHER POTENTIAL SOLUTIONS TO HELP ADDRESS GLOBAL CLIMATE CHANGE

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

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OPPORTUNITIES FOR ENERGY INNOVATION AND OTHER POTENTIAL SOLUTIONS TO HELP ADDRESS GLOBAL CLIMATE CHANGE

THURSDAY, APRIL 11, 2019

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The Committee met, pursuant to notice, at 10:04 a.m. in Room SD–366, Dirksen Senate Office Building, Hon. Lisa Murkowski, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

The CHAIRMAN. Good morning, everyone. The Committee will come to order.

We are here to continue our ongoing dialogue and conversation about the electricity sector, climate change and opportunities for innovative technologies that will further reduce our greenhouse gas emissions.

During a hearing we held in March, we discussed the reductions that have already taken place in the electricity sector, largely driven by nearly flat demand growth, low cost natural gas and the declining cost of renewable technologies like solar. Although we saw an uptick in 2018 driven by robust growth, U.S. emissions have declined in seven of the last ten years and are now 14 percent lower than in 2005. We know that that is impressive, but we also know that these trends are not always being replicated around the world. In fact, we know for a fact they are not.

When Dr. Fatih Birol, who is the Executive Director of the International Energy Agency (IEA), appeared before the Committee in February, he noted that global demand for electricity is on track to increase by 60 percent by 2040. As a result, electricity is now the "largest target for energy investment."

Greater use of electricity will almost certainly lead to an increase in global emissions. The opportunity we have in front of us is to foster an innovation ecosystem here in the United States that can lead to energy breakthroughs that deliver cleaner, more affordable and more reliable energy technologies.

The United States leads the world in energy innovation. Our national labs and universities, as well as the private sector, are developing technologies that could be deployed around the world to reduce our emissions. And that could occur through a number of pathways, whether it is advanced nuclear, carbon capture, utiliza-

tion and storage, energy storage or a technology that is just starting to show its potential.

We have seen firsthand the opportunity for moving to lower-emission technologies realized in my state. In Igiugig, an Alaskan village with a year-round population of about 70 people, a little bit more in the summer, they are installing a turbine system that will create emission-free electricity using river currents. The City of Kodiak generates nearly all of its electricity, almost 100 percent, from renewable resources, including hydropower and wind. In Southeast Alaska, the Haines Brewing Company is going to add more solar to their facility to power more of their beer production. And it is just kind of an added benefit that they make really great beer on top of it.

[Laughter.]

Alaska is feeling the effects of climate change, but our communities are making strides to responsibly reduce their emissions. Alaskans are pioneers, and we kind of view ourselves as this "living laboratory" for innovation. We figure if you can prove the technology out there in a sometimes harsh environment where it is very remote, if it works in the Arctic, trust me, it can probably work just about anywhere else.

We also recognize the transition to cleaner resources will take time. There is no overnight, magic-wand solution, as much as many would want it to be that way. But we simply do not have unlimited amounts of taxpayer dollars. We cannot simply replace markets with mandates and call it good. So even as we take real steps to promote clean energy, know that I am going to be working to fully protect our energy security as well as keeping our energy costs affordable.

This is a timely discussion, but also a nuanced one on the policy side. We have some impressive witnesses with us this morning to join the conversation.

We have Dr. Arun Majumdar, Co-Director of the Precourt Institute for Energy at Stanford. You have been a frequent visitor here before the Committee, and we are very pleased to have you back and for your leadership here.

We have Ms. Sarah Ladislaw, who is the Director and Senior Fellow at the Energy and National Security Program for the Center for Strategic and International Studies (CSIS). We are pleased to have you here.

Mr. Abe Silverman, we are kind of going back and forth here, Vice President and Deputy General Counsel at NRG Energy. It is good to have you before the Committee.

Mr. Robert Bryce, at the end, is a Senior Fellow at the Manhattan Institute, and Mr. David Sandalow is the Inaugural Fellow at the Center for Global Energy Policy at Columbia University.

So we have a great panel to help us discuss innovative solutions that will work to reduce our greenhouse gases.

With that, I turn to my friend and Ranking Member, Senator Manchin.

STATEMENT OF HON. JOE MANCHIN III,
U.S. SENATOR FROM WEST VIRGINIA

Senator MANCHIN. Chair Murkowski, thank you so much for convening the Committee and second hearing on climate change for this Congress, and we are very proud about that. And thank you all for being here. We really appreciate you bringing your expertise to the Committee.

I understand that we will also be having tech-focused hearings in the near future to take a hard look at carbon capture, nuclear, energy efficiency, renewable and storage technologies. I appreciate your ongoing commitment to innovation as a key solution to the climate crisis. I think this Committee has begun a very productive conversation. I am looking forward to continuing that with our witnesses today and in hearings ahead.

This year the Committee has begun to establish the facts about greenhouse gas emissions, particularly in the power sector, and we are looking at this problem from both domestic and international points of view. So far, the expert testimony we have heard has clearly stressed the need for technological advances to tackle the issue here at home but also strengthen America's position as a global leader in this space.

Since our last hearing on climate change, the International Energy Agency issued a report that showed energy demand around the world grew by 2.3 percent over the past year. Fossil fuels filled a lot of that demand, including in Asia, where coal-fired power plants have an average age of 12 years which means they are going to be around for a while. They are not going to retire any time soon.

Here in the United States we need to focus on commercializing technologies that can be used on our fossil fuel power plants and exported to markets around the globe. Projects like Petra Nova and NET Power capturing carbon dioxide from coal and natural gas power plants are shining examples of what is possible.

We need a moonshot to get carbon capture technologies to commercialization, and I am very happy to be introducing a bill today, along with my friend here, Chairman Murkowski, that will set the ambitious authorization levels that are needed. Our bill will focus the Department of Energy (DOE) on coal and natural gas technologies, carbon utilization and storage and atmospheric carbon removal.

The DOE and our national laboratories play an essential role in leading low-carbon energy innovation. Just last week Secretary Perry testified to the outstanding capabilities of the DOE and the labs in bringing new technologies to life, and many of those developments have kept our energy cost affordable in much of the country while reducing greenhouse gas emissions.

Programs like DOE's Advanced Research Projects Agency for Energy, or ARPA-E, and the Title 17 loan programs invest and demonstrate those technologies across the U.S. The Department's investment in solar research and development, for example, led to advances in solar panels that when demonstrated with financing from the loan programs kickstarted fast growing utility scale solar plants across our country.

The DOE plays a critical role in advancing innovation, and I believe their good work can be amplified through public-private partnerships. For example, Chairman Murkowski's Nuclear Energy Leadership Act (NELA), which I co-sponsored, will leverage these partnerships to build demonstration reactors that will play a vital role in decarbonizing the industrial sector. I believe in innovation, not elimination.

Now as former Energy Secretary Ernest Moniz has said, we need a "green real deal." As he, Bill Gates and other innovation champions have pointed out, we need a practical plan to address climate change that does not take technologies off the table or leave workers and communities stranded.

At the end of the day we need reliable, dependable and affordable power. So let's make headway on carbon reduction technologies for fossil fuels while also moving ahead with advanced nuclear and storage technologies. Let's also take a closer look how we manage the growing additions of renewable energy with a need for electric infrastructure and reliability.

We need to continue pushing the limits on research and commercialization so that every region finds the solutions that work best, because it is not a one-size-fits-all.

In that vein, I also believe it is our duty to recognize the historical contributions of energy producing states like West Virginia and Alaska. And I know we seem like maybe the couple talking about what we need and what needs to be done, but when you look at the devastating effects that climate has had in our states, it is real. It is not a myth. I will continue to say this, if the solution to climate crisis leaves West Virginia coal communities behind, then it is not a solution in any community that is left behind. As we move forward with the climate conversation, I am going to continue to consider global, national, regional perspectives.

With that, Chairman Murkowski, I think we have a big job ahead of us to find solutions, but I think that we are up to the task. And as part of the movement toward pragmatic solutions, I look forward to hearing from each and every one of you on this distinguished panel that we have assembled today.

So thank you for coming.

The CHAIRMAN. Thank you, Senator Manchin.

We do have a great deal to talk about this morning, and I look forward to the respective contributions from each of you followed by questions from our panel here.

I am particularly pleased that the Senator from Tennessee is here because he has laid down, as he usually does, a little bit of a road map from his perspective on some of these issues. So I look forward to the exchange.

I introduced each of you a little bit earlier, so let's just go straight into it.

Dr. Majumdar, if you would like to lead off the panel?

We would ask you to try to keep your comments to about five minutes. Your full statements will be included as part of the record.

Welcome.

STATEMENT OF DR. ARUN MAJUMDAR, JAY PRECOURT PROVOSTIAL CHAIR PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING, AND CO-DIRECTOR, PRECOURT INSTITUTE FOR ENERGY, STANFORD UNIVERSITY

Dr. MAJUMDAR. Chair Murkowski, Senator Manchin and all the members of this Committee, thank you for inviting me and giving me the honor to speak out here.

Just a little bit about my own background. I was the Founding Director of ARPA-E and also the Acting Under Secretary for Energy in the Department of Energy and thereafter was the Vice President of Energy at Google and now running the Stanford Precourt Institute for Energy. And I've been involved as advisor to many businesses and governments on this particular issue.

I just want to talk about four things: Number one is the impact and urgency of climate change, very briefly. The technology innovation that is needed for a transition to a low-carbon economy and how to get there. And then two policy innovations. One is a new infrastructure initiative to provide the infrastructure to deliver the low-carbon solutions to our people, and some market and regulatory policy to create the demand for low-carbon technologies. And finally, a booster shot on education because we need our people to be able to provide these services and be beneficiaries of this transition.

Very quickly on climate change. We normally talk about 1.5 or 2 degrees which is accurate, but I think we miss the point. It is the extreme that these weather events create that really hurts the people and our agriculture and our economy and our livestock. And I think we should be talking about the extreme weather condition. These extremes are happening more often, and we know that is going to happen. The uncertainty is we don't know where it's going to hit next. So we are really exposing all our citizens to a game of Russian Roulette.

To avoid the extremes, we have really, if you want to keep the temperatures below two degrees, we have really 20 years or less. That's the urgency that we have. And after that, the emissions have to be zero. That's the challenge that we have.

The question is what do we need to do? What are the technology innovation solutions? Well, we know about the good news stories. ULTRA achieved solar and wind. We know about the batteries that is leading to electrification and some of the, and the unconventional oil and gas.

That's all terrific but we still have 80 percent of our energy coming from fossil fuels around the world. And we need new technologies, grid-scale storage at one-tenth the cost of lithium-ion batteries, small modular nuclear reactors, new ways of air conditioning, zero net energy buildings at zero net cost, carbon-free hydrogen that can enable the steel and concrete industries to decarbonize and, of course, carbon capture and sequestration and utilization and finally, I would also add the use of the food and agriculture sector, not only to increase the food productivity but also to suck out carbon from the atmosphere and keep it and store it on the ground.

This is, if you think about it, this is essentially a new industrial revolution. It is a remake of much of our global economy. We're

talking about electricity, oil and gas, transportation, steel-concrete construction and food and agriculture. That's about $10 trillion per year of global economy. And this is a global race. No question about it.

And so, if you are to take the lead in this effort, it will decide the economic growth, the environment, the geopolitics and international security of the 21st century. That's what is at stake. And so, we must seize this opportunity.

As I've said many times before, we need to invest in R&D, ARPA-E. Budgets should be about $1 billion a year, but also the applied energy programs of the basic energy sciences in the Department of Energy.

As was pointed out, we have some of the best universities and national labs. The scientific infrastructure that we have in the United States is the best in the world. And we have amazing—as the Director of ARPA-E, I realized how much of an amazing capacity we have in the United States to innovate and deliver on these investments.

The two-policy innovation. Quoting Justice Brandeis, "Our states and local government act as laboratories of democracy." I think the diversity of energy needs that I have seen around the country in your states can offer this. This is the strength that we have to become the laboratories of this low-carbon industrial revolution that I was talking about.

In 1936 we had a Rural Electrification Act for the way the Federal Government provided low interest loans while local electric power cooperatives to bring electricity services to millions of Americans around the country and that transformed America.

We need a 21st century initiative to infrastructure to provide these low-carbon services to our people, and I've talked about what those technologies are. We need federal, state and local governments, along with the private sector to create the innovation pipeline for technologies and also to convene and create the permitting and speed up the permitting processes and create innovative policies to stimulate private sector investments.

The markets and regulation, I think there's a lot of discussion on carbon pricing. I think that will accelerate the transition of the carbon, the price on carbon.

And lastly I would say that education and training, we need the people to be able to get the benefit of this and provide the infrastructure that we need for this low-carbon economy.

Let me stop here.

Thank you very much.

[The prepared statement of Dr. Majumdar follows:]

Dr. Arun Majumdar, Jay Precourt Provostial Chair Professor, Department of Mechanical Engineering, Co-Director of Precourt Institute for Energy, Stanford University

ENERGY INNOVATION AND OTHER POTENTIAL SOLUTIONS TO ADDRESS CLIMATE CHANGE

US Senate Energy and Natural Resources Committee

April 11, 2019

Written Testimony of

Dr. Arun Majumdar
Jay Precourt Provostial Chair Professor
Department of Mechanical Engineering
Co-Director, Precourt Institute for Energy
Stanford University

Dr. Arun Majumdar, Jay Precourt Provostial Chair Professor, Department of Mechanical Engineering, Co-Director of Precourt Institute for Energy, Stanford University

Chairwoman Murkowski, Ranking Member Manchin and members of this esteemed committee. Thank you for giving me the opportunity to offer my thoughts on this important topic.

I am a Professor in the Department of Mechanical Engineering at Stanford University and the co-Director of the Stanford Precourt Institute for Energy that coordinates research, education and translation in energy across all of Stanford, the Hoover Institution and SLAC. Between 2009 and 2012, I had the honor to serve as the Founding Director of ARPA-E in the Department of Energy, where I also had the responsibility of the Acting Undersecretary of Energy that involved all the applied energy programs of the DOE. After leaving the DOE, I was briefly the Vice President for Energy at Google. I remain deeply engaged with the energy ecosystem across the world, either through work at Stanford or as a private citizen advising businesses, governments and other organizations. It is with this background that I will offer my perspectives on energy innovation and other potential solutions to address climate change.

Challenges and Opportunities Offered by Climate Change: When we discuss climate change, we often refer to the global average temperature rise of 1.2 ^{o}C since the beginning of the industrial revolution. While this is technically accurate, it misses the larger point: The true impact on human lives is manifested not by the average, but rather by the extreme weather conditions that the rising average produces, such as extreme heat and cold waves, droughts, excessive rain fall and flooding that affect agriculture, livestock, animal and plant diseases, forest fires, air pollution, and the overall health and well-being of Americans across the country. The certainty we now have is that these extremes will occur more often, but the uncertainty is that we can't predict where they will hit next. We are exposed to a game of Russian roulette.

If 1.2 ^{o}C can unleash extreme weather havoc, imagine what 2 ^{o}C would do. To stay below 2°C, the world can emit about 800 billion more tons of carbon dioxide. With a global emission rate of roughly 40 billion tons per year, that would leave just 20 years. Thereafter, the emissions must be zero. In the words of Reverend Martin Luther King Jr, we face the "fierce urgency of now."

It is the moral responsibility of our generation to envision the bright future of a low-carbon economy and hold the beacon of hope to illuminate a pathway that uplifts our people and ensures the security, prosperity and health of all Americans. What can we do?

Technology Innovation via Research and Development: We need affordable solutions to dramatically reduce greenhouse gas emissions from the energy system. Luckily, there is some good news. Today, three game-changing paradigm shifts are shaking up the global energy landscape: unconventional oil and gas revolution due to fracking of shale formations; electrification of transportation via lithium-ion batteries; and carbon-free electricity generation from wind and solar. The rapid cost reduction in these technologies due to R&D have created these tectonic shifts in the energy industry.

Despite this remarkable progress, fossil fuels still comprise 80 percent of global energy use. We have a long way to go. Reducing emissions is a billion-ton-scale problem and it needs billion-ton-scale affordable solutions. What are these potential solutions?

Dr. Arun Majumdar, Jay Precourt Provostial Chair Professor, Department of Mechanical Engineering, Co-Director of Precourt Institute for Energy, Stanford University

They include: grid-scale storage at one tenth the cost of lithium-ion batteries; small modular nuclear reactors at half the construction cost of today's reactors; refrigeration and air conditioning using refrigerants with no global warming potential; zero net energy buildings at zero net cost; using renewables to produce carbon-free hydrogen at the same cost as that from shale gas; decarbonizing industrial heat needed to make steel, concrete and chemicals and reimagining carbon-neutral construction materials; decarbonizing the food and agriculture sector, and leveraging agriculture to suck out carbon dioxide from the air and store it in the ground; and capturing carbon dioxide from power plant exhausts followed by sequestering it deep underground or using it make plastics or even fuels.

What I am describing is nothing short of a new industrial revolution. This is a remake of much of our economy – electricity, automobiles, steel, concrete, oil, gas, food, agriculture, etc. We stand at the doorstep of a colossal change of the energy sector worth $10 trillion per year, more than 10 percent of the global GDP. This change will impact every human being, and will shape the economy, environment, international security and geopolitics of the 21st century. In short, this global energy transition presents a historic opportunity for every country and region. And the race is on to seize this opportunity. We must ensure that the US remains globally competitive and maintains its technological lead.

To produce new solutions requires R&D based on science and engineering to develop both breakthrough new technologies and rapid improvements in current technologies. I have stated in the recent hearing of the House Science Committee on the Future of ARPA-E that its budget should be increased to $1B, and that we also need to increase the budget and effectiveness of the Applied Energy Programs and that of Basic Energy Sciences to address our nation's opportunities. With the best scientific infrastructure and talent in the world in our Universities and National Laboratories, and with the entrepreneurial spirit that is in the American DNA, the US has a remarkable capacity to innovate and deliver on these investments.

Policy Innovation: Research is necessary but not sufficient. These solutions need to help every American lead a more secure, healthy and prosperous life. For that, we must transition laboratory-scale proof of concept to commercial-scale solutions and an infrastructure to bring those solutions to all Americans. I have two policy recommendations to achieve this.

Low-Carbon Infrastructure Initiative with Federal-State-Private Sector Partnerships: As Justice Brandeis once said: "Our states and local governments act as the laboratories of democracies." The diversity of energy needs that our 50 states offer is our strength because they can become the laboratories of the new low-carbon industrial revolution as well.

In 1936, Congress passed the historic Rural Electrification Act where the federal government provided low-interest loans via local electric power cooperatives to bring electricity services and an enviable quality of life to millions of Americans across our nation. We now need a similar 21st century initiative to develop new and upgraded infrastructure to deliver low-carbon reliable and affordable energy services to all Americans. These include: energy efficient homes and buildings; intelligent electric grid that integrates large amounts of intermittent renewables, storage, as well as zero-emissions nuclear and fossil energy; electrification of public transit, automobiles and rail transport for moving people and freight; low-carbon heat and electrification

Dr. Arun Majumdar, Jay Precourt Provostial Chair Professor, Department of Mechanical Engineering, Co-Director of Precourt Institute for Energy, Stanford University

of our industry; low-carbon fuels; an agricultural revolution for higher food productivity and negative emissions; and many more.

Such an infrastructure initiative will require partnerships between federal, state and local governments along with the private sector, with the goal to: (a) create an innovation pipeline to use and de-risk new low-carbon technologies; (b) convene joint planning between cities, counties, states and regions to streamline and expedite siting and permitting processes; and (c) create innovative policies that stimulate private-sector financing and public-private partnerships. Low-carbon tax policies such as the Master Limited Partnerships (MLP) Parity Act could enable access to low-cost long-term capital, which is now available only for fossil-fuel infrastructure.

Markets and Regulations: Transition to a low-carbon economy requires either a direct or an indirect price on carbon. I personally prefer the direct approach, and in particular, the proposal by Secretaries Shultz, Baker and many other thoughtful economists: Charge energy producers $40-50 per ton of carbon dioxide emitted, which would incentivize corporations to invest in new low-carbon technologies and raise about $200-250B per year in the US. This could be returned to the people as carbon dividend so that every US citizen would receive a check of $600-700 per year, or $50-60 per month, thus making it progressive. A household could potentially earn about $200 per month. And those that use less energy will come out ahead.

While a price on carbon is effective for the supply side of energy where markets work, there are segments of our energy economy, especially energy efficiency on the demand side, where there are known market failures, ones where prices don't work because of split incentives and a variety of other challenges. What has worked effectively to reduce energy consumption since the 1970s are sensible regulatory measures such as efficiency standards for energy appliances and fuel-efficiency standards for cars and trucks. Buildings need special attention because they consume 40 percent of our primary energy and 75 percent of our electricity. Buildings codes are necessary but they are not sufficient because they focus only on design and do not account for how they are constructed and operated. We need operational performance-based whole building standards to ensure measurable energy efficiency performance.

Education and Training: To design, plan and operate a new low-carbon energy infrastructure, we need a skilled workforce. A few years back I was in a committee of the National Academy of Engineering that produced a report called "Making Value for America." One of the striking findings was that those Americans who did not complete high school found their unemployment rate steadily increase over decades, whereas ones who completed four years of college found their unemployment rate steadily decrease. Therefore, I cannot overemphasize the point that if we are to create the new low-carbon industrial revolution and lead the world, we cannot do so without our people. We must use this opportunity to ensure that our children and grandchildren get the basic education needed to flourish in the 21st century and are not left behind.

Final Comments: While the extreme weather events resulting from climate change pose daunting risks and challenges for all us, it is also an enormous opportunity to bring affordable and reliable low-carbon energy services to all Americans by leveraging our combined innovations in technology, policy and education. In the words of Rev. Martin Luther King Jr., "We are now faced with the fact that tomorrow is today. We are confronted with the fierce

Dr. Arun Majumdar, Jay Precourt Provostial Chair Professor, Department of Mechanical Engineering, Co-Director of Precourt Institute for Energy, Stanford University

urgency of now. In this unfolding conundrum of life and history, there is such a thing as being too late. This is no time for apathy or complacency. This is a time for vigorous and positive action."

The CHAIRMAN. Thank you, Dr. Majumdar.

Mr. Silverman, welcome.

STATEMENT OF ABRAHAM SILVERMAN, VICE PRESIDENT AND DEPUTY GENERAL COUNSEL, NRG ENERGY, INC.

Mr. SILVERMAN. Thank you. Good morning. My name is Abraham Silverman, on behalf of NRG Energy.

NRG is a 100 percent competitive power company which means that we have no captive customers and it is our shareholders, not ratepayers, that fund all of our initiatives. We have over three million retail customers nationwide with a large generation fleet that spans the dispatch order. We have nuclear. We have coal. We have carbon capture. We have natural gas. Battery, solar, wind and demand response. I think that's everything. So we bring a very practical practitioners view to this discussion today.

You know, when we think about climate change, we really start from two fundamental premises. The first is in order to avoid the worst consequences of climate change, we need to rapidly decarbonize our energy sector at a price consumers can afford. If we don't have affordability, we will fail. The second premise is that clean energy is not exempt from the laws of economics, nor should it be. You know, we look at American history and we see innovation and competition and competitive forces drive down prices, increase service and drive innovation in every possible sector. Markets are not broken. They simply need to be retooled for the 21st century needs and our concerns about carbon.

So when we think about what we need to do to drive the innovation, we need to refocus those markets on two primary goals.

One is competitive choice and the other is competition. So when we—we sell a lot of green product nationwide. Let's talk about choice. Our customers want this product. Let's give it to them. Right now, government, at many levels, restricts our ability to sell green power to customers and restricts the customer's ability to buy the power that aligns with their values. Why do we do that? We should get out of the way and let people shop and pick who they want to deal with. They want to fire your utility? Go ahead. Why not allow that?

We hear a lot of talk these days about big tech and, you know, problems, trust concerns, about them operating a platform and then selling products on the very platform that they dominate. That is exactly what happens today in the energy sector.

Everything we do when we innovate, we know that if we take it into a new market, outside of Texas which will solve this problem, we know that the local monopoly utility is likely to sell the identical product and compete with us, often using ratepayer funds. It's very difficult to innovate in that environment.

And whether we talk, whether we work toward ensuring a commercial environment free from unfair competition and domination by utilities, that's what the green new deal says or whether we want to quarantine the monopoly, as conservative and free market advocates put it. There's a shocking amount of consensus that enabling consumer choice will drive green outcomes faster and with less government regulation.

So step two, and these two steps are inseparable. Step two is that we need a robust, competitive market for free—for clean energy with understandable and predictable rules, operating is free as possible from intervention by government policymakers who want to pick politically driven winners and losers.

I attached a white paper to my testimony that lays out some specifics for, I think, a very innovative clean energy program that could be implemented at the state or federal level, but I'm going to give you three highlights.

First is we need to define the clean energy attribute that we want our market to get. Let's start there. We could use the available climate science to set targets and we will use the competitive market to achieve those targets in the least possible cost.

Second, the environment doesn't care how a carbon-free megawatt of electricity is generated. So why pay more if there's lower cost green options available?

We should have a market that rewards all innovators and all carbon-free megawatts equally.

Fourth, let the competitive market work because it will drive down prices and get us to where we need to be.

Unfortunately, the very concept of a pro-innovation, competitive approach to energy markets is under attack. In the absence of federal leadership, many states are falling prey to subsidies and to parties and companies that would rather compete for subsidies than compete in the market to deliver power, clean power, at the lowest possible cost.

So three, sort of, rules of thumb. One, don't redistribute precious tax dollars or ratepayer dollars via subsidies for technology that once it leaves the R&D phase. Second, don't lock customers into excessively priced contracts for specific clean energy technologies when clean energy, when other lower cost—when lower cost sources of clean energy are available. And three, certainly don't provide corporate welfare to existing power plants that are profitable under the guise of promoting carbon-free power.

I'll go ahead and stop there.

Thank you.

[The prepared statement of Mr. Silverman follows:]

NRG Energy, Inc.
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Testimony of Mr. Abraham Silverman

Chairman Murkowski, Ranking Member Manchin, members of the committee, I am honored to appear today to testify on the issue of climate change and what we can do as a country, using market forces, to reduce the greenhouse gas emissions that cause it.

My name is Abe Silverman, and I'm the Vice President and Deputy General Counsel of NRG Energy, Inc., a large, publicly traded independent energy company. What does it mean to be an independent company in the electricity space? It means that NRG is *not* a rate-regulated utility and, therefore, does not have captive rate-payers or a guaranteed rate of return on the capital that we invest. We have to earn our customers, and our shareholders – not our customers – bear the risks associated with the power plants we build and other projects that we undertake.

Our company is also proud to be a leader in acting to address climate change – even in the absence of a comprehensive, federal approach. We have embarked on that effort by establishing science-based greenhouse gas emission reduction targets and making the business decisions that are required to meet those targets in a way that provides consumers with the affordable, reliable and clean electricity they want while generating a return for our shareholders. For our shareholders, and for the general public, we provide granular disclosure of our progress towards meeting those targets. I am pleased to be here today sharing not only what we have done as a company but what we believe the federal government can do to facilitate broader participation – from energy companies and consumers alike – in the actions that are needed to mitigate climate change.

I. Introduction

Avoiding the worst consequences of climate change requires massive carbon reductions, and those actions must be *at a price that consumers can afford*. The American experience is the most impactful, most consistent force for enabling innovation, improving performance and lowering costs for consumers is, in a word, competition. It seems so obvious, but it is important to remind ourselves that clean energy is not exempt from the laws of economics, nor should we expect it to be.

To move towards an environmentally and *economically* sustainable future, our electricity markets need to be re-focused in two key ways.

- First, government needs to stop restricting the right of electricity customers, large and small, to procure the type of energy that aligns with their interests and values. Consumers nationwide want to buy green power. Why do we allow federal and state policies to stand in the way of giving consumers what they want?

- Second, a *competitive* clean energy market, open to all forms of carbon-free power, represents the lowest cost solution to meeting government-set carbon objectives. Indeed, wholesale electricity markets – where the objective is lowest cost reliability – utilize

government-set reliability targets, and then use the market to achieve those targets in the most affordable way.

In working to move towards an environmentally and *economically* sustainable future, there are also a few things that we must avoid. Specifically:

- Don't redistribute precious tax revenue or ratepayers' hard-earned dollars via subsidies for commercially mature generating technologies;
- Don't lock consumers into excessively-priced contracts for specific clean energy technologies when lower cost clean energy is available instead;
- Don't provide corporate welfare to existing power plants *that are profitable* under the guise of promoting carbon free energy; and
- Certainly don't make customers buy overpriced energy from specific well-connected companies.

A better approach is to define the attributes that we are looking for in our energy supply – in addition to reliability – and then incentivize private capital to compete to provide those attributes. Every carbon-free megawatt has the same value to fight climate change. When everyone competes, the lowest-cost resources win. Imagine a competitive, technology-inclusive, market where renewable energy, nuclear, carbon capture, or battery storage projects win because they provide the most green attributes at the lowest price; not because they have the biggest lobbying budgets.

Unfortunately, the concept of a pro-innovation, competitive energy market is presently under attack. In the absence of leadership from the federal government on these matters, many state governments are falling into the same tired pattern of handing out billions to prop up aging, uncompetitive facilities, or signing consumers up to contracts for expensive, one-off generating technologies. I understand that there are good reasons – at least good political reasons – why lawmakers sometimes support subsidies. Areas where power plants are located want to save the jobs. Owners are glad to use any argument to enable a stream of payments to their shareholders. Environmental groups sign on to bailout legislation because too often they see it as the only viable means of increasing green energy funding. While often well-intentioned, many of these programs lock in inefficient and expensive contracts for the next decade or more, without the benefit of ever having opened them up to competition. And they weaken – perhaps fatally – the competitive wholesale markets that companies like mine depend on, which means more jobs lost and other communities that feel the sting of plant closures.

As a society, we need a laser-focus on reducing emissions at the lowest possible cost. Subsidies defeat the markets, defeat innovation, and defeat job creation and new investment. Subsidies, in the form of long-term contracts, are not only wasteful, but risk locking customers into bad deals and forestall innovation for, in some cases, half a generation or more. If we fritter away our societal resources by treating green energy spending as corporate welfare or a jobs program, we risk missing out on the maximum carbon reduction possible and even leave ourselves vulnerable

to a homegrown version of the 'Yellow Vest' ratepayer revolt. In short, if we are serious about reducing carbon emissions, we should not be paying more for "boutique" clean energy when less expensive, but equally clean, options are available.

Today, the regions of our country with the most competitive electricity markets – where the objective is lowest cost reliability – provide unquestionable benefits, in the form of unparalleled reliability at the lowest possible price. Because of these markets, the cost of the electric energy we all consume, and the price we pay to maintain the capacity is needed to produce it, are the lowest they have been since restructuring.[1] Innovations in turbine technology led directly to more efficient use of natural gas – utilizing less fuel to produce a MWh and emitting less pollutants while doing it. Forced outage rates are down versus pre-competition levels. The cost of renewables and batteries are dropping. And a burgeoning demand response industry accounts for almost 10% of the supply stack in such key markets as PJM. All of these and other innovations were largely driven by the investment of shareholders' "at-risk" capital where there was no ability to pass the cost of potential failures along to captive ratepayers.

Addressing climate change in the power sector is – at this point – more of an economics problem than it is an engineering challenge. Our economic problem is that under the status quo monopolists' top priority will always be to defend their turf by seeking subsidies, including by cynically warning of layoffs. So long as legislators succumb to this political pressure, the innovation and consumer choice that could grow the economy and benefit the environment will be stifled. Fortunately, there are better alternatives.

II. Defining Climate "Success"

What does success look like in 2030, in terms of technology and utility business model?

On the grid, technology will have evolved to what we at NRG refer to as the "Four Product Future" – renewables, controllable demand, battery storage and fast-ramping natural gas – which combine to form the backbone of an affordable and reliable green grid.[2] In practice, this means that clean energy sources provide the majority of the electrons consumed. Homes, businesses and electric cars possess smart technology that will adjust electricity consumption seamlessly, forming flexible virtual power plants. Massive batteries, capable of storing electricity during times of plentiful sun or wind, inject that stored power back into the grid during times of high energy demand or low production. All while modern, efficient, natural gas power plants stand by to keep the grid humming and balance variability in consumption and production.

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[1] Notably, this reduction in costs for energy often has not been noticed by end-use consumers, because the monopoly providers of transmission and distribution service – utilities – spent billions of dollars on new Transmission & Distribution facilities which have dramatically increased customers' costs for those services even while energy costs have gone down.

[2] For more on the Four Product Future, please visit: https://www.nrg.com/insights/energy-education/the-four-product-future-transforming-the-energy-industry-today.html.

Behind the scenes, the electricity business model will have shifted in equally important ways. An open source platform for buying and selling electricity will exist in place of today's utility energy monopolies. Indeed, nowhere is the need to "quarantine the monopoly" more important than in the energy sector. Many have raised concerns about how big tech companies stifle innovation by operating a dominant platform – and then selling products on the very platform they control. This same conundrum permeates today's utility sector. Everywhere in the country, other than Texas, we are forced to sell our products through utility-dominated market platforms. Why should my company develop a new technology or product, spend the money to test and develop that product, if utility monopolies are then allowed to sell identical products on the platforms they control (often with risk-free, ratepayer-funded capital)? Thus, if we want to see innovation flourish, we need to confine the monopoly business model wherever possible.

III. Solutions

Step 1: Let Consumers Decide

The first big step is empowering consumers to choose, if they wish, to "green" their own power supply free from unfair competition and domination by monopolies. Public opinion polls have consistently found that overwhelming majorities, across parties, support taking action to address climate change. We ought to test if that's real, or not, by letting consumers vote with their pocketbooks. Among larger, commercial and industrial buyers seeking to green their power supply, we have seen powerful advocates[3] for open, competitive energy markets enter the fray. Why can't every single person in the United States decide, if they wish to do so, to 'fire their utility' in favor of picking a greener energy solution, and telling a larger pool of companies that they will have to compete – on the basis of cost – for that consumer's business?

Instead, customers in two-thirds of the country must battle powerful regional monopolists who fight to keep their stranglehold on the customer relationship, all in the name of protecting against profit erosion that may come with customers choosing to take their business elsewhere. In Florida, the utility lobby is so strong, that customers looking for the right to produce and sell solar power in the Sunshine state couldn't even get a constitutional amendment on the ballot last November. Fortunately, they will have another chance in 2020, as citizens take their fight for consumer choice to the ballot box again, this time in the form of an initiative requiring Florida to open its electricity markets.

But, the best part of this first step? Enabling enhanced customer choice doesn't cost taxpayers a penny. Putting the power to choose in the hands of more consumers presents a tremendous opportunity to let consumers take control of their own carbon footprint and for innovators to offer options to drive meaningful change. Still, unleashing consumer demand,[4] by itself, is only part of the solution.

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[3] *See, e.g.*, the Renewable Energy Buyers Association, a trade group representing large corporate buyers interested in sustainable solutions: https://rebuyers.org/.

[4] *See, e.g.*, The Myth of the Ethical Consumer, by Timothy Devinney, discussing the limits on consumer uptake of sustainable products.

Step 2: The Competitive Clean Energy Market

In a clean energy attributes market, NRG sees head-to-head competition between all zero-carbon resources as the lowest-cost means of achieving ambitious carbon targets. NRG has worked with the well-respected economists Drs. Kathleen Spees and Sam Newall of The Brattle Group to develop a competitive clean energy attributes market that could be implemented at either the federal, state, or multiple-state levels. The market design is laid out in a whitepaper attached to this testimony. It is also the basis of the Competitive Clean Energy Act, which has been introduced into the Illinois Legislature (Senate Bill 135 Amendment 2 / House Bill 125 Amendment 2, introduced by Sen. David Koehler). Our competitive clean energy market adheres to the following key principles:

- Technology-Inclusive: All zero-carbon resources – nuclear, wind, solar, carbon capture and sequestration, and voluntary emission reduction commitments – are allowed to compete to sell their attributes. Every increment of clean electricity, regardless of technology, is paid the same clearing price because every carbon-free megawatt has the same value to fight climate change. Everyone competes. Lowest-cost resources win.

- Quantity Matches Desired Carbon-Free Electricity Content: The market is designed to procure carbon-free energy in the quantities specified by regulators in each delivery year.

- Moves Carbon Price Signal into the Forward Timeframe: Forward market clearing moves the carbon investment price signal three-years into the future, allowing for new entrants to arrange for financing early in the development cycle.

- Financeable Contracts for New Winning Resources: New resources receive financial support (in the form of long-term contracts) that ensures they actually get built.

- Assigns Risk Appropriately: Private capital competes, not only on who has the best technology, but on accepting the lowest rate of return. Investors wear technology, regulatory, and performance risk.

- As Price Goes Down, Procurement Goes Up: Encourages early achievement of clean energy goals, because total clean energy purchases increase as price-per-megawatt decreases (i.e., a downward sloping demand curve).

- Allows Participation from Third-Parties: Opens up lowest cost procurement to third-parties (municipalities, private businesses, etc.) on a *voluntary* basis, encouraging even faster achievement of carbon goals.

Step 3: Re-Define Cooperative Federalism

NRG sees a clear need for federal leadership. Competition for long-term renewables contracts centrally cleared through a centralized market structure is the most promising option for achieving long-term decarbonization at the lowest possible cost. Even more promising would be a coordinated forward auction for renewable and conventional energy that co-optimizes the

procurement of renewable and conventional capacity, resulting in a total fuel mix that delivers the state's preferred carbon goals at the least possible cost, while also ensuring that reliability is maintained. Under such a system, states would achieve all of their environmental goals and consumers would save money in the process.

The main federal protector of competition in the energy sectors – the Federal Energy Regulatory Commission – is, unfortunately, nowhere to be seen on the clean energy playing field. For that matter, it seems to be nowhere in terms of basic protection of well-functioning markets. Congress gave the FERC exclusive jurisdiction over sales of electric energy for resale, as well as programs "affecting" or "in connection with" those sales. That means that FERC *should* have the authority—and, indeed, the duty—to ensure that rules or practices affecting wholesale rates are just and reasonable. But it has struggled to enact even basic efforts to harmonize federal competition policy with state subsidies. If the Agency wants to remain relevant in today's changing regulatory climate, it must take immediate steps to evolve wholesale market structures in a world increasingly concerned with carbon externalities.

If a state picks a politically-favored entity to receive lucrative long-term contracts without conducting a competitive solicitation that is open to all parties, then how can anyone say that the state has provided consumers with rates that are just and reasonable? In the absence of clarity on that question, there is absolutely a role for federal oversight.[5] In such scenarios, there must be a federal role if the Federal Power Act is to have any meaning as a consumer protection statute.

States are increasingly incorporating carbon, jobs, tax, and other externalities into their energy policies. In isolated cases, states have adopted jobs and economic development programs which "mix and match" environmental and economic goals in a deliberate effort to avoid federal jurisdiction. Clearly, the answer cannot be that FERC is powerless to prevent this type of consumer abuse. Congressional leadership is key to helping FERC refocus on preserving the benefits of competition and restoring a functional cooperative federalism relationship.

Electricity markets in the regions of the country that have elected to restructure and minimize the role of monopoly utilities provide billions in annual savings to consumers while delivering reliability. These highly competitive markets, however, are likewise sidelined from the fight against carbon pollution because we have not added carbon considerations into their core missions of ensuring reliability at the lowest possible costs. As a result, we have denied consumers access to the markets most able to deliver the lowest priced carbon abatement.

Strong Congressional leadership can help break the log-jam that has threatened competitive markets. States are (understandably) reluctant to stall progress on meeting carbon goals. This leaves an opening for Congress to redefine cooperative federalism by, for example, allowing

[5] For example, regulators in Illinois and New York committed ratepayers to more than $10 billion in no-bid contracts over the next decade on keeping economically inefficient nuclear plants operating in the wholesale market. Both states implemented these programs without ever testing these investments to determine whether consumers could have received more carbon "bang-for-their-buck" elsewhere. Other states risk falling victim to the same rhetoric, as evidence by recent bailout efforts in Pennsylvania.

states to set the desired carbon content of their electricity, but leave it for federal regulators, running some of the most fiercely competitive markets in the world, to accomplish that goal at just and reasonable rates.

How States, Cities, and Customers Can Harness Competitive Markets to Meet Ambitious Carbon Goals

THROUGH A FORWARD MARKET FOR CLEAN ENERGY ATTRIBUTES

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April 2019

Notice

This market design proposal was prepared by authors from The Brattle Group for NRG. The views presented are those of the authors and do not represent the opinion of The Brattle Group or its clients. Any errors are the sole responsibility of the authors.

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Executive Summary

Across the U.S., over 100 cities and two states (Hawaii and California) plus the District of Columbia have already made the commitment to transition to 100% clean or renewable energy in the coming years.[1] In the past year, Xcel Energy became the first large utility to commit to 100% renewable energy, and the University of California system committed to 100% clean energy on a short timeline by 2025.[2] Nearly three-quarters of the Fortune 100 companies have adopted sustainability and renewable energy goals.[3]

Achieving these ambitious public and private goals will eventually require replacing much of the current fleet of generation that relies heavily on carbon-emitting coal and natural gas. But such an ambitious transition to clean energy is unlikely to happen on its own, and it is unlikely to be achieved cost-effectively using traditional policy instruments. What's needed now is to acknowledge that transitioning to 50% or 100% carbon-free energy will require some fundamentally different and better policy tools. In this whitepaper, we propose a new forward clean energy market (FCEM) in order to harness competition and innovation. The FCEM would provide a competitive, regional market for clean electricity attributes. It would enable states, cities, and customers to achieve their ambitious carbon targets at lower costs. Furthermore, it would complement existing competitive wholesale electricity markets.

The transition to clean energy is unlikely to happen on its own because, at least in restructured states, investment and operating decisions are driven by competitive market forces that do not account for the cost of carbon emissions. Thus the markets underprovide clean energy relative to states' carbon targets. This shortfall has led many states to intervene in the electricity markets to achieve their policy goals. One approach is to procure and subsidize certain non-emitting resources directly. Such an approach may appear expeditious but does not necessarily identify the lowest-cost solutions among the diverse and evolving set of possibilities. The lowest cost path to decarbonization will be discovered only through innovation and broad competition among all types of resources and industry players, and across locations with different natural solar and wind patterns. Only market-oriented approaches will do that. But how can markets incorporate environmental values and find the least-cost solution?

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1 Sierra Club, "100% Commitments in Cities, Counties, and States," 2018.

2 David Roberts, "For the first time, a major US utility has committed to 100% clean energy," December 14, 2018, published in Vox.

Robyn Schelenz, "UC makes bold commitment to 100 percent clean electricity," October 29, 2018, published by the University of California.

3 Advanced Energy Economy, "2016 Corporate Advance Energy Commitments," December 2016.

The classic economists' approach is to internalize emissions costs into markets by charging for emissions, through either taxes or cap-and-trade. Carbon pricing is considered the most efficient approach because it creates the broadest possible competition for abating carbon, not only from carbon-free sources, but also from efficient gas-fired generation that can displace higher-emitting coal generation. Carbon pricing is challenging to implement effectively, however, if applied to only a subset of states, cities, and customers that wish to decarbonize within a highly interconnected interstate market. The main challenge is that electricity production and associated emissions can shift or "leak" from the areas that price carbon to those that do not, unless complicated border adjustments are applied. For regions that are not able to implement carbon pricing, our proposed FCEM can efficiently guide the transformation to clean energy.

The FCEM proposal is built around two core ideas: the first is *competition*, which is critical for identifying the least-cost solutions to a problem this big and with such varied possible solutions; this proposal ensures broad competition across carbon-free energy sources (although it does not incorporate substitution of relatively low-emitting natural gas generation for higher-emitting coal generation, as a carbon price would). The second is *smart product design*, where the marketable product is a clean energy attribute credit (CEAC), which is a certificate for 1 MWh of *clean energy attributes*, not including the energy itself. A marketable product reflecting just the clean energy attributes perfectly complements existing wholesale electricity markets. This allows the combined markets to find the least cost combination of technologies to meet traditional system needs while decarbonizing the grid. Traditional system needs are already rewarded through existing wholesale markets (for energy, capacity, and ancillary services), while the policy requirement to decarbonize will be rewarded through the new market (for clean energy attributes). Together, the wholesale markets and the FCEM can ensure that both system reliability and decarbonization targets are achieved at the lowest possible cost.

The FCEM would be administered by a state agency, a multi-state organization, or even an independent system operator. States and cities could submit demand bids for CEACs, consistent with their clean energy goals. Companies or retail electricity suppliers that wish to procure additional clean energy to meet private customers' sustainability goals could also submit demand bids.

Supply offers could be submitted by any resources that are qualified as contributing to the state's clean energy objectives, which could include nuclear plants, renewable generation, and any other resource that does not directly emit carbon and thus helps displace emissions. The market would clear only the lowest-cost supply offers to meet demand, and establish a competitive clearing price at which all transactions settle.[4] Cleared offers would be paid that price for a delivery term of one year (for most resources) or for a multi-year period of approximately seven years (for new

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[4] It is also be possible to establish technology-specific "carve outs" to ensure a minimum share of the procurements would achieved from nascent technologies that may be higher cost. For example, see the "targeted resources" provision described in a proposal by The Brattle Group and several coalition partners, "A Dynamic Clean Energy Market for New England," November 2017.

resources, in order to provide developers with sufficient long-term price certainty to support financing new projects).

To pursue a market-oriented, cost-reducing approach, a single state or group of states could collaborate to develop and implement the a clean energy market through an appropriate agency, possibly with a governance model similar to that used in the Regional Greenhouse Gas Initiative (RGGI). The proven success and low costs achieved through such a design would likely attract additional future participation from more producers, states, cities, and customers over time.

I. Why Use A Competitive Market Approach to Achieve Clean Electricity Goals?

The next years and decades will see massive investment in clean energy. Many states, cities, and corporations have pledged to meet most or all of their energy needs from non-emitting resources. This means not only replacing current emitting generation, but also building enough to electrify transportation, heating, and many industrial applications. Electrification is currently the most promising opportunity to cost-effectively decarbonize much of these sectors. The cost of this ambitious investment program could be very high. To minimize the cost, it will be essential to leverage competitive, market-based approaches.

A. Traditional Approaches Will Become Too Costly if Scaled Up to Meet Policy Goals

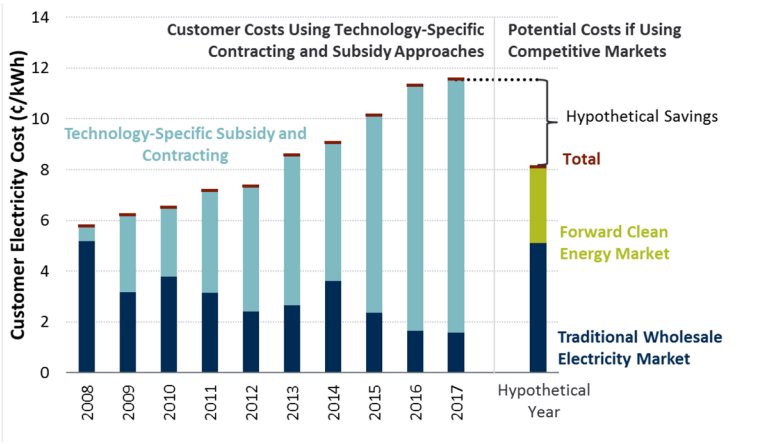
Although traditional technology-specific subsidies and contracts have succeeded in driving clean energy investment in some jurisdictions, these approaches can be expensive, at are odds with existing wholesale electricity markets, and may transfer risks from producers to customers. In many places, total customer bill impacts have been modest so far, but only because the associated goals have been modest as well. The costs of current approaches could rapidly increase as aspirations for a low-carbon electricity system rise.

These concerns have already been borne out in other jurisdictions, where more ambitious objectives met through traditional policy approaches have often led to significant cost problems that have sometimes eventually triggered customer or policy backlash. For instance, over the last decade, the Ontario government signed 20-year contracts with many solar, wind, and other non-emitting resources as part of the overall goal to achieve its current 90 percent clean electricity grid. However, this momentous achievement has come at a high cost: residents there have seen their electric bills nearly double since 2008 even as solar and wind prices have come down every year, as shown in Figure 1. This illustrates the additional costs that can be imposed if policymakers lock in too many inflexible contracts at high prices, even if they are expected to be the lowest-cost alternative at the time those resources are procured.

Looking forward, Ontario is pursuing the opportunity to save customers billions of dollars by transitioning away from their traditional technology-specific contracting approaches and toward

a market-oriented, resource neutral market.[5] Figure 1 illustrates the costs reductions that could be achieved if Ontario were to use a set of unbundled, resource-neutral markets for maintaining the 90% clean energy fleet as well as for meeting traditional wholesale electricity market needs.

Figure 1
Ontario Electricity Customer Costs While Achieving a 90% Clean Energy System Compared to Illustrative Costs of Achieving 90% Clean Electricity via a Competitive Market



Sources and Notes:
Values represent wholesale commodity costs, excluding transmission and distribution. Historical traditional electricity market costs represent the weighted-average Ontario Energy price (dark blue), and the Global Adjustment (aqua), which includes resource-specific subsidy and contracting costs. Hypothetical future year costs if using a competitive clean energy market are adapted from a Brattle modeling assessment of the future Ontario market (not intended to reflect a "but-for" estimate of historical costs). Source: "The Future of Ontario's Electricity Markets: Preliminary Study Results," November 30, 2018. The Brattle Group.

B. Broad Competition will Minimize the Costs of Achieving Carbon Goals

Using a broad market-based approach will focus the industry's incentives toward meeting current and future carbon goals at the lowest possible cost to customers. A truly market-based approach will spur:

- Competition among different developers of the same technology type, who may be able to innovate on more cost-effective ways to design, manufacture, install, or operate assets;

[5] The Brattle Group, "The Future of Ontario's Electricity Market: A Benefits Case Assessment of the Market Renewal Project," April 20, 2017, prepared for Ontario Independent Electricity System Operator.

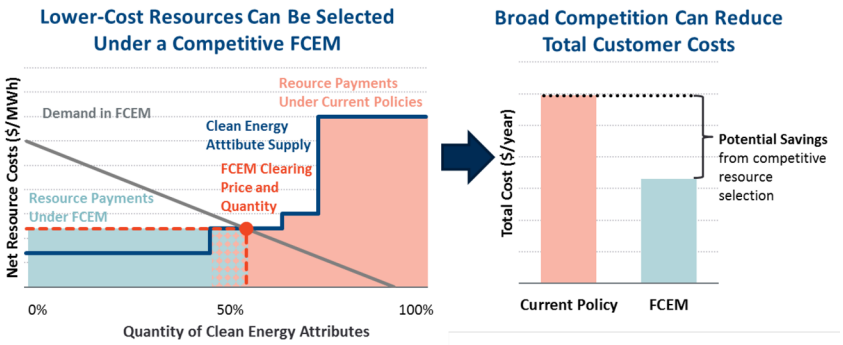
- Competition among different resource types with varying costs and operating characteristics (this is especially valuable as the cost of these technologies are rapidly changing and declining at differing rates);
- Competition among resources across disparate locations (because greenhouse gasses are global pollutants, the specific location of emissions—and the specific location of abatement—does not affect the value of carbon abatement);
- Competition between existing and new resources; and
- Competition among different clean energy resources that provide a variety of grid services, which are compensated via existing wholesale markets for energy, ancillary services, and capacity.

The cost-saving effects of resource-neutral competition are demonstrated in Figure 2, which compares the costs of achieving state clean energy goals if using a system of targeted subsidies (in red) to the costs if using a competitive FCEM (in blue). The left-hand side of Figure 2 shows illustrative costs of a variety of different resources and technologies that could be used to achieve carbon or clean energy goals, with resources sorted in order of increasing costs. The resources highlighted in red would be those selected under traditional policy approaches using technology-specific subsidies and bundled contract procurements. The resources developed under a suite of traditional policy approaches would likely support the development of both high-cost and low-cost clean resources, resulting in relatively high total costs (red bar on the right-hand chart).

The left-hand chart also illustrates the cost-savings that can be achieved with a competitive market. Under a resource-neutral FCEM auction, all sellers will offer in at the minimum price they need in order to develop a clean energy project.[6] The auction can then select only the lowest-cost resources regardless of technology, age, location, or other non-price attributes (resources highlighted in blue). This approach may result in procuring an entirely different mix of resources than would have been supported under traditional policy approaches, including some very low-cost resources that may not have been eligible to participate. As shown on the right-hand chart, the overall costs of such a program can therefore be much lower to achieve the same decarbonization goals (alternatively, the same program budgets can be used to achieve much more ambitious carbon reductions).

[6] This discussion assumes a uniform price auction format; pay-as-bid auction formats incentivize different (strategic) bidding behavior and may result in somewhat less efficient outcomes.

Figure 2
Competitive Markets Drive a Lower Cost Procurement of Clean Resources



This market-based approach can also greatly benefit (primarily corporate) customers wishing to privately exceed state-level targets. These individual customers can benefit from a centralized market platform that would help them purchase their desired clean energy resources at lower costs. This platform would enable private buyers to procure large or small quantities of clean electricity supply at a competitive price with minimal transactions costs, counterparty risks, and or other complexities that arise when contracting individually with developers. Developers, too, will benefit from a platform that offers a predictable opportunity to sell clean energy under standardized terms and under a level playing field. Thus, having a centralized competitive market can improve economic efficiency and lower costs by connecting suppliers with customers who want to set their own targets, goals, and commitments.

C. Technology-Neutral Approaches Maximize Efficiency and Reward Innovation

Another benefit of this proposed market is that it would allow competitive forces to identify the least-cost mix of resource technologies to reach carbon policy goals, and incentivize suppliers to find ways to deliver cleaner energy at lower prices. This market design rewards innovation in carbon abatement technologies and provides revenues for potential developers, new entrants, entrepreneurs, and existing generators alike as they seek to reduce carbon emissions. Competition across technologies avoids relying on policymakers to accurately predict the future of costs and innovation, or to pick "winners" and "losers." Instead, the market determines how the best mix changes over time to meet increasing decarbonization targets.[7]

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[7] As described in our prior work in New England, there are also variations of the FCEM that could introduce technology-specific carve-outs to support a preferred technology. Such a mechanism would

Continued on next page

For example, the most cost-effective mix of clean resources could evolve over time. At first, the lowest-cost existing supply might come from older nuclear and hydro resources that need refurbishment to continue operating. Next, high-quality wind resources could provide the lowest-cost clean energy. This may transition to solar resources as the best wind sites become saturated and peaking needs make consistent daytime production most important; this shift to solar would be incentivized based on the combined incentives of the FCEM and the unbundled value for other grid services. Finally, the most valuable technologies may transition to storage and demand response after intermittent supply displaces most fossil generation. Our proposed FCEM will facilitate and encourage this industry evolution. Continuing advances in unbundled energy, ancillary service, and capacity market designs will provide a strong complement to the FCEM to ensure appropriate incentives to avoid curtailments and incentivize flexible resources such as storage.[8]

The central benefit of this markets-based approach is that it incentivizes creative market participants to identify new solutions and technologies that policymakers cannot hope to think of. The ability to attract on that creative potential will be essential to meeting aggressive targets quickly and at low cost.

D. A Market Solution Can Better Align with Wholesale Electricity Markets

A market-based approach such as the FCEM has additional benefits beyond efficiency and cost-effectiveness. One key benefit is improved alignment with existing wholesale capacity, energy, and ancillary service markets. Most importantly, a marketable product reflecting just the non-emitting attributes of qualifying sources perfectly complements existing wholesale electricity markets for energy and reliability attributes. This allows the combined market forces to identify the least cost bundle of multi-attribute resources to meet multi-attribute system needs. This concept is grounded in a mechanism that has been proven to be effective: electricity generators already produce multiple marketable attributes, including energy, capacity, and various ancillary services products. The existing markets incent entities pursuing private profits to make investment and operating decisions that maximize the system value they provide across these multiple products. Adding a non-emitting resource attribute to the bundle of products that can be sold will

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increase costs as compared to a fully resource-neutral approach. For more information, see The Brattle Group and several coalition partners, "A Dynamic Clean Energy Market for New England," November 2017.

[8] Note that the full carbon abatement value of flexible resources including demand response and storage can also be incentivized under an FCEM on a resource-neutral basis with other clean technologies, but only if there is a mechanism for accurately tracking their carbon value (which traditional renewable energy credit markets have not previously done). For additional discussion of an FCEM approach that fully enables storage and demand response see The Brattle Group, "A Dynamic Clean Energy Market for New England," November 2017.

Continued on next page

incentivize all market participants to identify the best resources to jointly supply both traditional grid services and the demand for non-emitting supply.

One important issue in several electricity markets today is the "out-of-market" treatment of resources that receive payments for clean energy attributes. In ISO-NE and PJM, such resources are not allowed to directly participate in capacity markets without being subject to the so called "minimum offer price rules" (MOPR).[9] These rules limit the ability of resources receiving out-of-market clean attribute payments to offer and clear in the capacity market. This can result in two unsustainably detrimental outcomes from a state policy perspective: first, the resource adequacy value of these resources may not be fully reflected, leading to more capacity on the system than needed to meet reliability requirements; second, that customers that are paying for the "out-of-market" resources end up having to pay twice for capacity.

Our proposed approach is that clean resources receiving payments through the clean energy market should be considered "in-market" for purposes of interfacing with the wholesale capacity market, including for purposes of market power mitigation, such as the MOPR. Our design thus bridges the divide between state carbon goals and wholesale market reliability and least-cost planning criteria.[10]

II. What Would a Competitive Clean Attributes Market Look Like?

Our proposal centers on a regional forward auction for the clean attribute of electricity production, known as clean energy attribute credits (CEACs). In the most basic implementation of this approach as we describe on this paper, the clean attribute product would be similar to unbundled renewable energy credits (RECs) that are used to track renewable energy generation today. A REC represents the clean attribute of energy generation, and unbundled RECs are often sold separately from the original electricity production that generated it. Each REC is tied to a specific delivery year when it is generated. The CEAC product procured in the FCEM would have these same characteristics. Thus, the FCEM can be viewed as a natural successor to existing REC markets. However, the proposed market would incorporate several advantages over existing markets.

In the FCEM, state policymakers would mandate a quantity of carbon-free power that they wish to procure for all customers by a given delivery year. The state's mandated Clean Energy Standard

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[9] For a more comprehensive discussion of this issue, see a recent discussion paper by Kathleen Spees, Johannes Pfeifenberger, Samuel Newell, Judy Chang, "Harmonizing Environmental Policies with Competitive Markets," July 2018.

[10] The economic rationale for removing the MOPR on such competitively-procured clean energy resources is that a state non-emitting attribute program that is competitively administered and open to all qualifying resources on a non-discriminatory basis that satisfies the principles of competition underpinning the competitive wholesale electricity markets.

becomes the minimum quantity of carbon-free electricity, while allowing for easy and cost-effective over-achievement. At the state level, policymakers can express a desire to accelerate emissions reductions by utilizing this market design that procures more carbon-free power when prices are more attractive (but moderating goals in alignment with budget caps if prices are high).

The FCEM also creates a platform that allows private parties to buy additional carbon-free power. This allows companies, municipalities, public power entities, retail electric providers, and others to exceed the clean energy standard in a cost-effective manner and with minimal overhead costs. Each participant would translate its policy or corporate sustainability goals into a quantity of clean energy, and bid for this quantity in the FCEM. This allows states and customers to control their future and to procure the quantity clean energy resources that matches their policy goals to phase out fossil-fired carbon emitting resources over time.

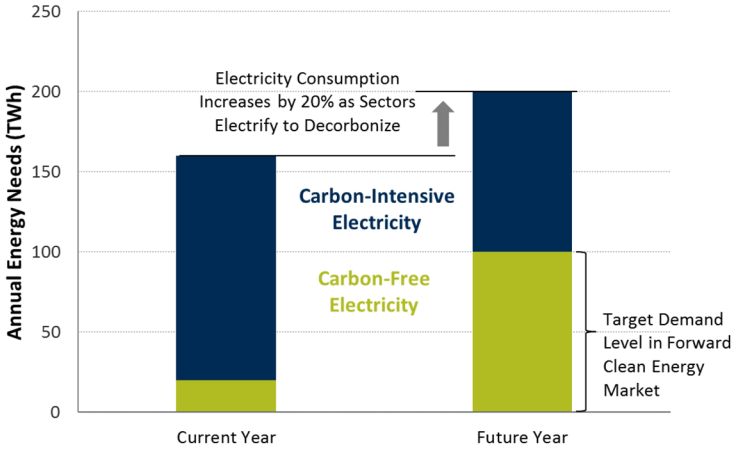
On the supply side, generators who own or are developing resources that produce carbon-free electricity would offer to sell CEACs in the delivery year at a price they choose. The forward auction would set the quantity and price of the CEACs procured for the given delivery year.[11] By procuring carbon-free energy for a future year, the new market would incentivize investment in non-emitting resources. It would provide renewable developers access to a predictable source of revenues, including multi-year commitments for new resources that help to mitigate investor risk and reduce financing costs. Overall, this approach assigns regulatory risk to the states/customers, while leaving technology and cost risk primarily with market participants and investors, who are best able to manage that type of risk.

A. Translating Policy Goals into Market-Based Demand for Clean Electricity

For states that have policy commitments to serve a certain share of demand with clean resources such as through a Clean Energy Standard, these targets would be straightforward to translate into demand in the forward auction, as shown in Figure 3. In this example, the state currently has a small share of clean generation but has a target to meet 50% of demand with non-emitting supply by a certain year. Demand is forecasted to grow to 200 TWh by that future year, so the state target demand level for the clean energy attribute would be 100 TWh. Any willingness to procure more CEACs at low prices, or desire to procure less at high prices, would be represented through the specific shape of each states' demand curve for CEACs.

[11] The delivery year is the period for which resources are committing to produce clean energy in the forward auction.

Figure 3
Example: Translating State Goals into Forward Clean Energy Market Demand



State-offered demand would also be submitted within the context of a commitment to sustained participation over many years in order to mitigate regulatory risks that may be introduced by uncertainties in the total auction demand levels over time. For example, states could be required to commit to a certain minimum demand for a ten-year period, with adjustments allowed as consistent with changes to total load.[12]

Cities, companies, public power, and retail providers might develop their own targets to meet internal sustainability or green energy goals or offer cleaner energy to their customers. These may be in excess of what the state will already procure on their behalf, or instead of it, if located in a state that is not participating in the auction. Thus, each potential market participant has full control of its level of demand for clean energy attributes. Each state or individual buyer would submit its demand for clean energy and the maximum willingness to pay for a specific quantity of CEACs.[13] The demand from each state and individual buyer would be summed into an aggregate market-wide market demand curve, representing to total quantity of CEACs desired by the market at each price, as illustrated in Figure 4.

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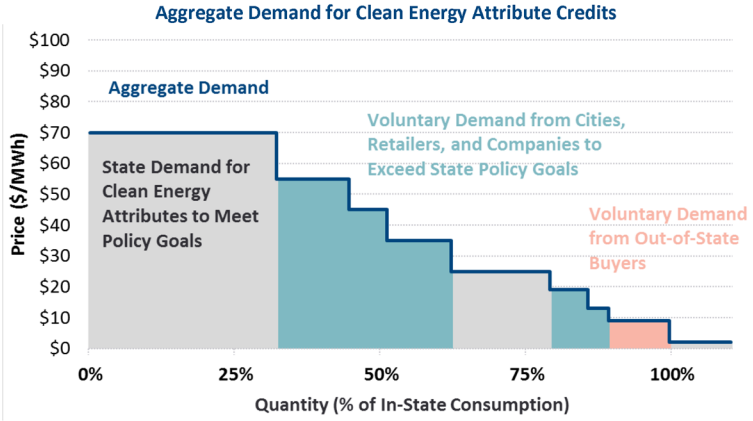
[12] Though states could commit to procuring that quantity in repeat auctions over the ten-year period, individual sellers would not be guaranteed ten-year contracts. Instead, sellers would have an opportunity to sell into the auction on a year-by-year basis, but would have to compete each year to sell at the lowest price.

[13] Buyers could also use more complex demand curves to represent their willingness to purchase CEACs as a function of price. This would allow them to represent higher willingness to purchase CEACs at low market prices if desired.

Figure 4
Aggregate Demand for Clean Energy Attribute Credits



Sources and Notes:
States could also choose to submit a smoothed downward-sloping demand curve (such as a cost-neutral curve that aligns with the program budget cap) but states' demand is shown in three blocks here for simplicity. Represented as the percentage of a specific state's demand, although the design will maximize benefits if extended to clear supply and demand from many states together.

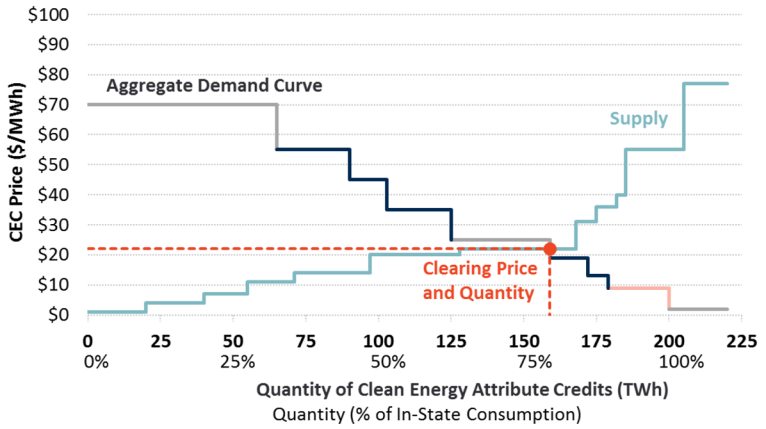
B. Procuring the Most Cost-Effective Clean Electricity in a Competitive Forward Market

A forward auction, which occurs three years in advance of the delivery period, would bring together market participants on the supply and demand side of the market. On the supply side, resources would offer in their estimated clean generation capability at a specified price for the delivery period. As the market is designed to be competitive, offer prices should reflect sellers' costs of clean generation, including going-forward costs of being online in the delivery year. Sellers whose resources are also valuable for providing energy, capacity, or ancillary services could offer at low prices into the FCEM because the large majority of the resource's costs will already be paid for by revenues from other wholesale electricity markets. The uniform-price auction would attract and reward the most cost-effective resources. More expensive options would not be selected.

On the demand side, states with mandatory targets for meeting clean electricity goals would make up the majority of bidders. For bids won by state entities, the costs and associated CEACs would be passed through to the retail providers within that state. Other participants including private companies, municipal utilities, electric cooperatives, and retail providers could submit voluntary bids to procure additional clean energy. These participants could use their cleared bids to meet corporate sustainability goals or to offer green energy rates to end use customers.

Aggregate market supply and demand would be cleared in a single-price auction as depicted in Figure 5. The resulting clearing price and quantity would be set at the intersection of these curves, and would determine which resources have an obligation to provide the clean attribute and how much they would be paid for it.

Figure 5
Example: Clearing the Forward Clean Energy Market



C. Features for Advancing Beyond Traditional Clean Attributes Products and Markets

While this proposed FCEM will be similar to existing REC markets as described above, it would also have several important features that will allow it to cost-effectively achieve far more carbon reductions at lower costs than traditional REC markets:

- Technology-Neutral Participation: unlike REC markets with tiered participation that segments different types of non-emitting resources and that tend to exclude some clean resource types like nuclear and resources existing prior to established cut-off dates, the FCEM would maximize participation of all non-emitting supply on a uniform basis.
- Mechanisms to Support Price Stability: a graduated demand curve for different quantities of CEACs at different prices in the forward market, and a spot auction conducted right before the compliance deadline would mitigate the boom or bust pricing tendencies of existing REC markets.
- Capability to Support Financing of New Clean Energy Resources: several design elements would support financing for new resources better than existing RECs, including a multi-year commitment for new resources and a forward auction to support financing of resources with longer development timeframes.

In addition, the proposed market would be flexible and easily tailored to integrate with other enhancements to advance beyond traditional clean energy products and markets. One potential drawback of the market as presented here is its focus on incentivizing non-emitting resources while admittedly not providing incentives for lowering the emissions through fuel switching from coal to gas generation as carbon pricing could.

In an even more efficient but somewhat more complex version of this market, the clean attribute product could be more directly tied to the marginal carbon abatement value of the resources in each year. Thus, resources that are expected to displace more carbon, due to the alignment of their generation profile with carbon emissions on the system, would create more CEACs. In the most advanced version of this approach, the quantity of CEACs created by a non-emitting resource could be dynamically related to the marginal rate of emissions in the market at every location in every real-time market interval. This would incentivize producers to identify opportunities to cost-effectively displace more carbon faster.[14]

III. A Potential Roadmap for Implementation

With sufficient political will, the proposal outlined in this paper could be implemented relatively quickly as a much-needed complement to the existing electricity markets (energy, ancillary services, and capacity). The initiative to create this market could be taken by a single state, a group of states, a group of clean energy buyers, or an RTO.

The market would work best if a state agency such as the Illinois Power Authority (IPA) or an independent organization with a structure such as RGGI or an RTO were to conduct the auction and manage the updating of market rules. If an independent group is chosen to administer the market, a new organization could be created or an existing company specialized in supporting the trade of commodity products could be contracted. If an RTO operates the market, the states could ask the RTO to create the auction and recover any administrative costs from market participants. The responsibilities of this organization would be to administer and update rules, register buyers and sellers, qualify supply, support measurement and tracking, maintain credit requirements, and implement settlements. A state regulatory body would likely maintain regulatory approvals and authority to change market rules, or as in the context of RGGI, the independent entity could develop model rules in collaboration with participants. These rules would then need to be separately ratified by each participating state authority.

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[14] The "standardized clean energy attribute credit" would represent 1 MWh of clean energy that displaces a certain quantity of carbon, for example 1,100 lbs of carbon per MWh. Resources would be credited with creating more CEACs if they inject clean energy into the grid at times and places that displace more carbon (and would produce fewer or no CEACs if injecting at times and places that do not displace fossil generation). For more discussion of this idea, see a proposal by The Brattle Group and several coalition partners, "A Dynamic Clean Energy Market for New England," November 2017.

Finally, state utility commissions or environmental agencies would develop state demand bids, in alignment with the commitments to achieve carbon abatement and maintain market sustainability. Large companies, cities, public power, retail providers, and other interested parties could also develop and submit voluntary demand bids.

The competitive marketplace is fit-for-purpose to identify and reward faster, cheaper, and better ways to decarbonize the electricity grid. When developed, the FCEM would allow states, retail providers, end customers, and clean energy suppliers to work in harmony to accomplish the ambitious goals before us.

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The CHAIRMAN. Thank you. You have a lot more there, and we will have an opportunity to pursue that in the questions. So thank you for that, Mr. Silverman.

Ms. Ladislaw, welcome.

STATEMENT OF SARAH LADISLAW, SENIOR VICE PRESIDENT; DIRECTOR AND SENIOR FELLOW, ENERGY AND NATIONAL SECURITY PROGRAM, CENTER FOR STRATEGIC AND INTERNATIONAL STUDIES

Ms. LADISLAW. Thank you, Chairman Murkowski, Ranking Member Manchin and members of the Committee. Thank you for the opportunity to appear before you today.

I'd also like to additionally thank the Committee for its commitment to fostering a constructive dialogue on the urgent need to tackle global climate change challenges.

The United States is one of the most energy and innovation-advantaged nations on the planet. I firmly believe that we have every conceivable tool at our disposal to chart a viable pathway to a net zero emissions, resilient energy system at home and also provide global leadership in the strategies and technologies that can bring sustainable and affordable energy supplies to the growing and developing populations of the world. We simply need to decide to do it.

Your previous hearings on this topic have been robust and very useful. I have four major points to add to the already strong and important messages that you've received.

First, as both of you mentioned at the outset, energy is playing an increasingly important role in how states and regions think about economic opportunity. The state level interest can be an important catalyst for innovation in climate solutions as well as creating the economic opportunity sought by states.

Federal level policymakers should pay close attention to how energy development, innovation clusters, worker retraining programs and energy policies and incentives in general fulfill or fall short of delivering on the expected economic outcomes at the state level.

Most pertinent to this hearing, there are important lessons learned about how to create successful innovation clusters and help make the most out of R&D spending at the state level. Federal involvement in these clusters can help shape them to be more successful.

Second, it's true that innovation defines the art of the possible when it comes to meeting society's basic energy needs and it's at the heart of U.S. economic competitiveness. But innovation is the means to a solution and not a solution in and of itself. Innovation in this context, must be harnessed to achieve certain societal goals, and it is in setting these goals that the biggest disagreements often exist.

Currently, the international community has organized itself around three energy relevant goals. Reduce emissions for the purposes of dealing with climate change, eradicate energy poverty, and ensure secure and resilient energy systems.

The second important takeaway for this Committee is to use these agreed upon global goals to drive the relevant conversations

around climate change both within your jurisdiction and across the committees with whom you work.

Too often, these three challenges are pitted against one another to suggest that achieving one means neglecting or working against the other. While tradeoffs do exist, the solutions are not mutually exclusive and innovation and climate policies should work toward solutions that contribute to achieving all three goals simultaneously and reject the notion that one goal is more important than the other.

The third main message is that we need to seriously commit to a robust innovation agenda, and Senator Alexander's bill is one example of how to do that.

Relative to the challenges we face that all-of-the-above energy challenge is in the danger of becoming a cliché for muddling along without making any decisions. We need an all in on the all-of-the-above strategy where we redouble our commitment to make every resource compatible with the needs of a 21st century energy strategy, low-carbon, cost competitive and secure.

Among experts there is a great deal of agreement about the suite of technologies we need to drastically reduce emissions. Supporting all of these solutions includes but should not be limited to increased R&D spending.

Moreover, in a world where we're confronting large-scale industrial competition from other countries, particularly China, we should consider more deliberately creating an industrial strategy around certain technologies where we want to compete for a host of climate competitiveness, security and economic reasons. Advanced nuclear, carbon capture and sequestration, battery storage and electric vehicles are all areas that immediately come to mind.

The fourth and final takeaway for this Committee is that moderate climate policy need not be mediocre. In my written testimony I give two examples. Greater support for energy efficiency through DOE programs, efficiency standards, regulations and tax incentives and also, the implementation of policies like a clean energy standard. They're all places where moderate federal climate policy could make a really big difference.

The key to moderate climate policy is to use policy and regulatory mechanisms that people recognize, trust and use today but be ambitious about their targets and implementation. There will be ongoing efforts to build support for economy wide strategies like a carbon tax which will be necessary as part of a suite of policies to develop deep decarbonization.

But there are things that we can do to make notable progress on this issue right now and are needed to supplement the impacts of a more robust approach to innovation.

Thank you.

[The prepared statement of Ms. Ladislaw follows:]

CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES

Statement before the

Senate Energy and Natural Resources Committee

"Examining Opportunities for Energy Innovation and Other Potential Solutions to Help Address Global Climate Change"

A Testimony by:

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April 11, 2019

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Chairman Murkowksi, Ranking Member Manchin and Members of the Senate Committee on Energy and Natural Resources, thank you for the opportunity to appear before you today to discuss opportunities for energy innovation and other potential solutions to help address global climate change.

I would like thank the Committee for its commitment to fostering a constructive dialogue on the urgent need to address global climate change. For far too long this discussion has been about avoiding near-term costs and not about maximizing the potential long-term benefits. As I will lay out in my testimony, the United States is one of the most energy-advantaged nations on the planet. Not only do we have every conceivable tool at our disposal to chart a viable pathway to a net zero-emissions, resilient energy system at home, but we also have the unparalleled ability to provide global leadership in the strategies and technologies that can bring sustainable and affordable energy supplies to the growing and developing populations of the world. We just have to decide to do it.

This Committee has already covered the importance of energy innovation and climate change in several other hearings this Congress. The testimony and discussions in those hearings has been robust and useful. My testimony seeks to reinforce some of the key messages from those hearings and add a few additional recommendations and insights to the record.

Harness energy as a source of economic opportunity

For the last three years, the CSIS Energy and National Security Program has devoted itself to studying the way in which the energy landscape in the United States is changing and how the public and private sectors are responding to a host of new energy realities. Last week we published the first of two major studies examining how energy's role in the U.S. economy is shifting and next month we will release a second study on the ways in which energy is used as a tool of economic development and social mobility in states and regions around the country. Both studies have recommendations for policymakers that this Committee may find useful as you continue to address these important issues.[1] This section of my testimony (drawn from the above-mentioned report) outlines the changes in both the U.S. energy landscape and the U.S. economy and describes some of the most pertinent findings of this work.

The shifting energy landscape

Driven by shifts at home and abroad, U.S. production, trade, and consumption of energy has changed dramatically over the past two decades. In 2000, the United States was the world's largest energy consumer and its largest emitter of greenhouse gases—positions that it has since ceded to China in 2009[2] and 2005[3] respectively. To the great consternation of many policymakers at the time, the country seemed all but certain to increase its reliance on foreign energy supplies, with the Energy Information Administration (EIA) forecasting in 2000 that the

[1] Sarah Ladislaw and Jesse Barnett. "The Changing Role of Energy in the U.S. Economy." CSIS, March 2019. https://csis-prod.s3.amazonaws.com/s3fs-public/publication/190329_LadislawandBarnettWorkshop_WEB_v4.pdf.
[2] Energy Information Administration, "International Energy Statistics," Raw Data, https://www.eia.gov/beta/international/data/browser/.
[3] BP, Statistical Review of World Energy, Raw Data (London: BP Plc, 2017), https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html.

American economy would, on a net basis, import nearly 16.9 million barrels of petroleum per day by 2020[4] —an estimate that, as of 2018, has been revised down to just less than 1.0 million barrels per day.[5] At the time, this pessimism reflected the relatively limited menu of U.S. energy options. Two decades ago, domestic oil and natural gas production was stagnating, solar and wind constituted less than one percent of the total energy mix,[6] and the electric power sector was dependent on coal for 55 percent of generation[7] compared to 30 percent today.[8]

Yet even with these seismic shifts, other elements remain essentially unchanged: despite rapid growth in renewables, the United States still relies on fossil fuels for the vast majority of its energy; most electricity continues to come from centralized sources; and the transportation sector still is dominated by liquid transportation fuels, with electric vehicles playing a small but growing role in the overall fleet.

Energy in the broader economic context

It is important to reflect upon the ways in which U.S. energy trends and policy priorities are often related to the broader economic context in which they exist. For the first decade of this millennia, the global economy largely was driven by the growth of China and other emerging markets, with nearly a quarter of world GDP growth between 2000 and 2017 directly attributed to the former.[9] High commodity prices and concern over potential resource scarcity colored the U.S. perspective on its growing import dependence for energy resources like oil and natural gas. Resource scarcity also bolstered the rationale for the development of alternative energy resources such as nuclear power, biofuels, hydrogen, solar, and wind.

In 2008, the global financial crisis, the Great Recession, and a decline in commodity prices created new imperatives to stimulate economic growth and reform those sectors—namely, the financial and housing markets—that posed a systemic threat to the global economy. The pre-crisis period of high prices and incentives for alternative energy, followed by several years of fiscal and economic stimulus, created an environment where renewable energy costs dropped, not only for relatively proven technologies such as wind turbines and solar photovoltaic panels, but also for their more nascent peers, including algae fuels, cellulosic ethanol, solar heat pumps, offshore wind, tidal power, and enhanced geothermal. U.S. unconventional oil and natural gas production, responsible for the largest increments of oil and gas production growth in history for several years in a row, also grew out of this period.

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[4] Energy Information Administration, "Annual Energy Outlook," Raw Data (2000), https://www.hsdl.org/?view&did=15936.

[5] Energy Information Administration, Annual Energy Outlook with projections to 2050 (Washington, DC: EIA, 2018), https://www.eia.gov/outlooks/aeo/pdf/AEO2018.pdf.

[6] Energy Information Administration, "Supplement Tables to the Annual Energy Outlook 2002, Table 88 Renewable Energy Capacity, Generation, and Consumption," Raw Data (2002), https://www.eia.gov/outlooks/archive/aeo02/supplement/index.html.

[7] Ibid.

[8] Energy Information Administration, "Electricity Data Browser, Net Generation," Raw Data, https://www.eia.gov/electricity/data/browser/.

[9] Exclusive of Hong Kong SAR and Macao SAR. Source: World Bank, DataBank, Raw Data, https://databank.worldbank.org/data/reports.aspx?source=2&series=NY.GDP.MKTP.CD&country=

Together, these energy and economic trends have fundamentally altered the American energy outlook from scarcity to abundance—energy is no longer assumed to be destined to be ever-more expensive and increasingly difficult to deliver but instead more readily available and from a diversified portfolio of sources. Today, the United States and the global economic context have grown more complex. Although the world has grown more prosperous and has seen record numbers of people lifted out of abject poverty, the rise of economic inequality within developed countries has challenged political agendas around the world. In the United States, this concern typically manifests in debates over jobs and wage stagnation. Even with rates of unemployment and GDP growth that are the envy of much of the developed world, economic malaise continues to pervade much of the public discourse, with discouraging long-term growth prospects for unskilled workers and a likely global economic slowdown proving particularly worrying.

Energy, however, has been a source of largely good news for the U.S. economy, with cheap energy prices, an increasingly diverse pool of sources and suppliers, and—until recently—lower greenhouse gas emissions all providing a welcome exception to an otherwise bleak economic outlook. But the overriding atmosphere of economic anxiety has also altered public expectations of the role that energy should play in both the U.S. economy and society writ large. Whether as an input, an end product, or a source of externalities, energy increasingly is expected to serve as a creator of jobs and an enabler of local economic opportunity—a reality that, fair or not, is relevant for public policymakers and energy companies alike.

Energy and economic development

This rings especially true in states and local communities around the country that seek to harness energy resources to create economic opportunity for their respective communities. The role of energy differs throughout the country, however, with a handful of states accounting for the vast majority of each major type of energy production. Six states account for 85 percent of U.S. onshore oil production. Nine states provide 87 percent of onshore natural gas production. Eight states produce 84 percent the nation's coal. Ten states produce 83 percent of the corn and 85 percent of U.S. ethanol. Ten states generate 81 percent of U.S. conventional hydro, and ten states account for 76 percent of wind generation (five of which are geographically co-located).[10] For each of these states, energy represents an important source of investment and job creation, even if it does not account for an overwhelmingly large portion of the state economy or job-base.

Even states without significant basic energy resources seek to create economic opportunity through efforts to create innovation clusters, whose activities can extend far beyond energy. To date many states have created innovation clusters with the goal of attracting investment and creating an innovation ecosystem that will pay technological and economic returns. The literature on these efforts is not encouraging – noting that many innovation clusters fail to deliver the desired outcomes. As Joseph Parilla and Mark Muro of the Brookings Institute note in a forthcoming paper there is a, "gap between the recognition that clusters play an important role in and economy that demands concentration and specialization and the practical ability to develop

[10] Kevin Book. "America's State-Level Energy Haves and Have Nots," CSIS, January 2019. https://csis-prod.s3.amazonaws.com/s3fs-public/190128_Book_HavesHaveNots_0.pdf

initiatives that help firms within cluster become more competitive and spur growth."[11] The pair attribute this to hopes being set too high, erroneous targeting of goals, superficial execution or lack of follow through. There are a number of lessons learned from existing innovation cluster strategies that can help inform cluster initiatives going forward. The relative success or failure of various innovation cluster initiatives should serve as a useful guide to federal, state and local policymakers who want to learn from mistakes of the past.

It is also worth noting that regional innovation clusters are not only attractive for economic development reasons but also an important part of the U.S. innovation ecosystem. According to the recent report, *Advancing the Landscape of Clean Energy Innovation*, regional innovation clusters are a big part of why America's innovation system has been so successful to date. The national laboratories, university systems, and connections to state and local government as well as private industry all serve an important and reinforcing role in fostering a cycle of innovation.

The first takeaway for this Committee is that energy is playing an increasingly important role in how states and regions think about regional economic opportunity. This state-level interest can be an important catalyst for innovation and climate solutions as well as creating the economic opportunity sought by states. Policymakers should pay close attention to how energy development, innovation clusters, worker retraining programs, and energy policies and incentives in general, fulfill or fall short of delivering on expected economic outcomes.

Use global challenges as a guide

In previous hearings, this Committee has heard a true and familiar refrain – innovation is a critical component of the global energy system. Innovation defines the art of the possible when it comes to meeting society's basic energy needs, and it is at the heart of U.S. economic competitiveness against that backdrop. But innovation is the means to a solution and not a solution in and of itself. Innovation in this context must be harnessed to achieve certain societal goals, and it is in setting those goals that the biggest disagreements often exist.

Countries around the world face a similar challenge – provide affordable and reliable energy services to enable economic growth and societal development, while maintaining a healthy environment. Throughout much of modern history, countries have struggled to achieve this trifecta, often falling short on environmental measures, especially during periods of industrialization, or reliability measures, often due to a variety of economic or security issues. Along the way, innovation and sound public policy have greatly improved countries' ability to meet these challenges in new and more effective ways.

Currently, the global community is organized around three shared challenges that the United States should continue to prioritize. The first and most daunting, is to decarbonize the world's energy system as part of a comprehensive strategy to address global climate change. According to the latest assessments conducted by the Intergovernmental Panel on Climate Change (IPCC) and the U.S. government's own National Climate Assessment (NCA), the impacts of a changing climate are more and more pronounced with each passing day and the world is not on track to

[11] (forthcoming paper) Joseph Parilla and Mark Muro, "Revisiting Cluster Strategies," paper prepared for CSIS Workshop on Energy as a Source of Economic Growth and Social Mobility, January 2019.

reduce emissions commensurate with globally stated goals or provide sufficient resources and strategies to adapt to the anticipated changes.[12] There are many potential pathways available to achieve atmospheric stabilization but the world is not currently tracking with any of them.

The second goal is to end energy poverty by providing universal access to modern and sustainable energy services.[13] Here too the world has seen encouraging progress but is not on track to achieve universal access by 2030. According to the International Energy Agency, the number of people without access to electricity has declined to below 1 million people for the first time in 2017. The number of people without access to clean cooking facilities has also been declining but still accounts for 2.7 billion people. The challenge is particularly pressing in sub-Saharan Africa where 600 million people (57 percent of the population) have no access to electricity.[14]

The third goal is to ensure a resilient and secure energy system. Energy security has long been thought of as freedom from the importation of oil or the provision of energy resources during times of acute scarcity. Modern day energy security is about a great deal more – from assuring reliability of energy supply in energy systems in transition, to providing enhanced resilience to cyber-attacks, to planning for anticipated sea level-rise, severe storms, or forest fires.

The second important takeaway for this Committee is to use agreed upon global goals to drive the relevant conversations around climate change both within your jurisdiction and across committees with whom you work. Too often these three challenges are pitted against one another to suggest that achieving one means neglecting or working against another. While trade-offs do exist, the solutions are not mutually exclusive. Innovation and climate policy should work toward solutions that contribute to achieving all three goals simultaneously and reject the notion that one goal is more important than another.

Innovation and competitiveness

Concern over the decline in U.S. competitiveness in the field of innovation is not a new theme. In 2007, the National Academies of Science, in response to a request from Congress, published "Rising Above the Gathering Storm," which captures the consensus recommendations from a committee of experts about how the United States should seek to maintain its expertise in field of innovation. Report authors wrote: "Although many people assume that the Untied States will always be a world leader in science and technology, this may not continue to be the case inasmuch as great minds and ideas exist throughout the world. We fear the abruptness with which a lead in science and technology can be lost-and the difficulty of recovering a lead once lost, if indeed it can be regained at all."[15]

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[12] Intergovernmental Panel on Climate Change, "Special Report on Global Warming of 1.5 degrees", https://www.ipcc.ch/sr15/ and U.S. Global Change Research Program, Fourth National Climate Assessment

[13] SDG7

[14] Laura Cozzi and Aaron Koh, "Population without access to electricity falls below 1 billion," International Energy Agency, October 30, 2018. https://www.iea.org/newsroom/news/2018/october/population-without-access-to-electricity-falls-below-1-billion.html

[15] National Academies of Science, Committee on Prospering in the Global Economy of the 21st Century. "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future." 2007. Page 3. https://www.nap.edu/read/11463/chapter/2

In the intervening decade, maintaining the competitiveness of the U.S. economy, particularly in the area of innovation has been a near constant pre-occupation of policymakers. And yet, it is not clear that the United States is making the kind of unambiguous progress towards maintaining its competitive edge relative to international competitors. Several panelists in earlier hearings correctly attributed this to several factors. The first is the sheer amount of technological changes and rapid pace of innovation both in and outside the energy sector – in areas such as the next phase of the digital revolution, advancements in biotechnology, nano-technology and autonomous systems.[16] Anticipating the ways in which these kind of society transforming technologies will impacting energy-use is exceedingly complicated in no small part because they include major unanswered questions about the human/technology interface and the role of policy and society in shaping the extent of the role they can and should play. For example, smart cities can be greatly enabled by the deployment of sensors, the ability to apply machine learning to manage systems, and the ability to derive valuable systems information from the data collected. This all depends on the willingness of policymakers and people to allow for this level of observation and intervention in their daily lives. It also requires a good deal of trial and error to understand what types of intervention elicit different human responses.

Second, is the growth of innovation as a strategic economic priority for many countries around the world, most pressingly China, and their growing capability to deliver outcomes at higher levels of innovation chain (rather than simply replicating and manufacturing technology). According to a recent report from the Council on Competitiveness, "China's investment in R&D has more than doubled since 2010, reaching $451 billion in 2016, second only to the U.S. investment, and set to outpace the United States by the end of this decade. China has overtaken the United States in science and engineering publications. China has an 18.6 percent world share, while the United States has a 17.8 percent share. China has posted double-digit growth rates in international patent filings in every year since 2003, and now lags only the United States in patents filed."[17]

Third, and finally, experts note ongoing shortcomings in the U.S. innovation system that can and should be addressed as another reason for concern over the U.S. competitiveness. According to the Council on Competitiveness, "There are many factors that affect a county's ability to innovate and compete. This includes levels of investment in R&D, the availability of capital including venture capital to fuel start-ups and innovation at critical stages, the availability of talent, the environment for entrepreneurship, and the general business environment including taxes and the level of business regulation. These elements are different in countries around the world, and can play a significant role in a country's competitiveness and capacity for innovation."[18] It should be noted, however, that consistent support at much higher funding levels from Congress and across disparate administrations has been noted as a desirable goal by the

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[16] For more fulsome discussion see earlier testimony from Deborah Wince-Smith, President and CEO of the Council on Competitiveness. https://www.energy.senate.gov/public/index/cfm/files/serve?File_id=4DDAD4C6-A45D-4300-B926-C74FF0C6FB49

[17] "2018 Clarion Call, The launch of the National Commission on Innovation and Competitiveness Frontiers," Council on Competitiveness, https://www.compete.org/storage/reports/2018%20clarion%20call%20final.pdf p. 34

[18] Ibid, 30.

American Energy Innovation Council and, indeed, was that state goal and U.S. commitment as part of Mission Innovation. The recently released study *Advancing the Landscape of Clean Energy Innovation* has a number of ideas about how to organize and better integrate the nation's energy innovation system.

Picking winners

Beyond the concern over spending levels and the innovation process there is a general concern about government "picking winners." This aversion, echoed in earlier testimony by Secretary Moniz, asserts that the government cannot possible divine or prescribe innovation outcomes and should therefore avoid backing any one technology over others. This is a sound principle as far as it goes but it also completely divorced from the reality and history of U.S. energy and innovation policy. Through policies and investments, the United States has historically and continues to presently, signal preference for certain fuels and technologies over others. So long as the backing of a particular technology or fuel is done as part of a portfolio of options there is nothing inherently wrong with this approach. This extends all the way from research and development to the deployment phase of various technologies. In a recent report from Senator Rubio on the U.S. response to the Made in China 2025 strategy, he writes, "Nations desire high-value, high-labor content production, and compete for industries and innovations that drive it. In a world of state competition for valuable industries, a domestic policy of neutrality is itself a selection of priority. 'Not choosing' is a choice, however it is made. The critical policy consideration, then, is not whether states should organize their economies, but how they should be organized."[19] This perspective suggests that rather than not choose winners, the U.S. should think much more deliberately about technologies and industries where it wants to be competitive (Senator Rubio suggests high-value and high labor content industries as the priority) and try to create outcomes along those lines. While this seems like a dramatic departure from the laissez-faire attitude typically ascribed to U.S. economic and innovation policy, it is, in reality, a call for a more concerted focus on the structure of the U.S. economy, the priorities we should have for our own growth and competitiveness, and a more deliberate conversation about how we propose to achieve those outcomes.

In the energy sector, deciding on a portfolio of priority technologies is actually not terribly hard to do as there is widespread agreement among experts about the suite of technologies that are necessary for decarbonizing the energy system. What exact mix of fuels and technologies will ultimately be deployed is not as certain, nor should it be entirely preordained. The International Energy Agency offers a useful assessment of "where technologies are today and where they need to be according the IEA's Sustainable Development Scenario." According to this analysis, of the 38 technologies required to meet this scenario (i.e. to "meet the Paris climate goal of well below 2 degrees C, deliver universal energy access and significantly lower air pollution") the world is currently on track to make the required progress on four of them – solar PVs, LEDs, data centers and networks, and EVs. The world is not on track to meet eleven of the technology goals and is making progress but in need of more effort on the remaining twenty-three (see below).

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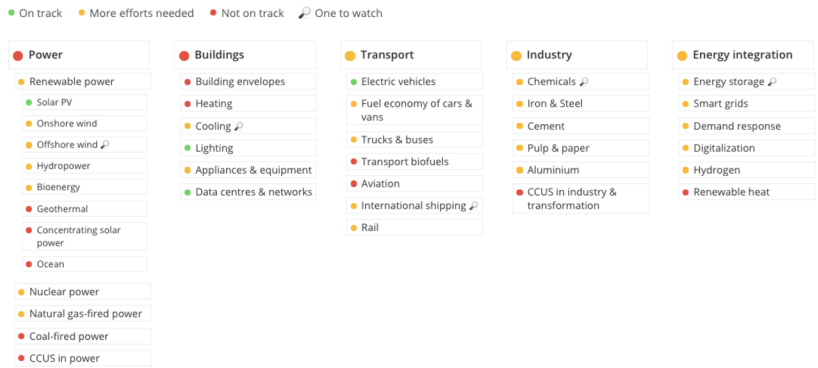
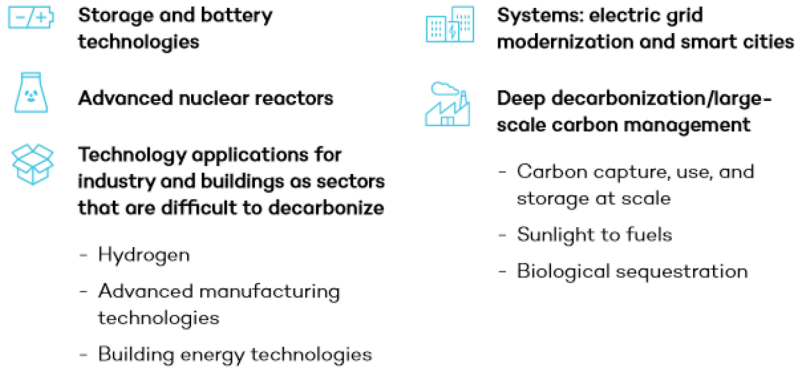
[19] "Made in China 2025 and the Future of American Industry," U.S. Senate Committee on Small Business and Entrepreneurship, February 12, 2019. https://www.rubio.senate.gov/public/_cache/files/0acec42a-d4a8-43bd-8608-a3482371f494/262B39A37119D9DCFE023B907F54BF03.02.12.19-final-sbc-project-mic-2025-report.pdf



Source: https://www.iea.org/tcep/

This suite of technologies is not vastly different from the "technologies with breakthrough potential" put forth in the *Advancing the Landscape for Clean Energy Innovation* report. The IEA technology tracker list combines existing energy technologies and resources as well as efforts to improve the cost and performance of next generation or more advanced versions of existing technologies. The "technologies with breakthrough potential" list below prioritizes technologies across a range of criteria that make them ripe for a breakthrough meaning technological advancement that could lead to widespread deployment.



Source: *Advancing the Landscape for Clean Energy Innovation*

The disagreements arise when it comes to determining the relative merit of each technology as a solution. In practice, policymakers, investors, scientists, and private companies all have a complex array of incentives that lead them to prefer one technological solution over another.

These preferences are not, in and of themselves, a problem and can lead to a healthy competitive environment for technological advancements and added incentives to ensure deployment. It is a problem, however, when preference for one fuel or technology leads to support for only that fuel or technology on a widespread basis or to the detriment of other technologies or solutions. One way of mitigating this outcome within the federal R&D portfolio is to ensure that technological progress is based on performance metrics.

The third important takeaway for the Committee is that an all of the above energy strategy has become a cliché for muddling along without making decisions. We need an "all-in" on all of the above strategy where we commit to devise strategies to make every resource compatible with the needs of a 21st century energy environment – low carbon, cost-competitive, and secure. This can also include more deliberately creating an industrial strategy around certain technologies where we want to compete for a host of climate, competitiveness, security or economic reasons.

Moderate climate policy need not be mediocre

Recent reports on climate change present a stark reality. The impacts of a warming climate are becoming more frequent and severe, as the science suggested they would. Moreover, as a society, we are not preparing to address those present-day challenges much less stave off the worst impacts projected on the horizon.

Some argue such alarming news requires a drastic response; anything less simply will not rise to the level of the challenge. Others argue that a dramatic approach is impractical and implausible given the cost and lack of political will. Still others are so skeptical of the cost of action, the severity of the problem, or society's ability to collectively solve the problem, that they see all but a few climate-related policies or investment as throwing good money after bad.

Proposed climate strategies ranging from "do nothing" to "change everything" reveal how polarized the federal government is on this issue. The American public is not nearly as polarized. Though disagreements do exist across party lines and relative to various solutions, there is widespread agreement that climate change is occurring and that it is a problem.[20] There is also increasing recognition that there are real and tangible benefits to addressing it. The disagreements are, as you well know, about the right policies and approaches. Investing in technological innovation alone is not likely to deliver enough emissions reduction on time to make a meaningful contribution to the solution. The policy environment plays an important role in shaping and expediting the transition to a net-zero emissions future.

A moderate approach to addressing climate change should seek to make progress where progress can be made and build support for additional policies as confidence grows in our ability to navigate towards a net-zero carbon world. To do this, moderate climate policy should pick from policies that a) have a proven track record of working and b) have the best chance of finding broad-based support. A moderate path forward should include both efforts to reduce emissions

[20] Abel Gustafson, Parrish Bergquist, Anthony Lesierowitz, and Edward Malabach, "A Growing Majority of Americans Think Global Warming is Happening and are Worried," Yale Program on Climate Change Communications, February 21, 2019, http://climatecommunication.yale.edu/publications/a-growing-majority-of-americans-think-global-warming-is-happening-and-are-worried/.

and build resilience and the ability to adapt to a changing climate. Here existing federal policy and state examples can serve as a guide for reform of existing policies or new policy implementation.

Clean Energy Standard

For example, 29 states, the District of Columbia and 3 territories have mandatory renewable portfolio standards. In addition, eight states and one territory have voluntary renewable portfolio standards. The scope and scale of the various RPS programs differ from state to state and several of these states have updated or are in the process of updating them.[21] According to one study, nearly half of the renewable power generation capacity built in the Untied States since 2000 is associated with a renewable portfolio standard. And while the impact of renewable portfolio standards on market outcomes has diminished in recent years, they still play an important role in certain regional markets where they support between 70-90 percent of the new capacity additions.[22] In addition, at least four states have adopted zero emissions credit programs to support existing nuclear generation.[23] One idea to build on this state-level momentum is to introduce some sort of national clean energy standard (CES). According to one recent study conducted by Resources for the Future, a clean energy standard, "typically refers to a technology-neutral portfolio standard that requires that a certain percentage of utility sales be met through 'clean' zero – or low-carbon resources such as renewables, nuclear energy, coal or natural gas fitted with carbon capture, and other technologies."[24] Increasing the number of technologies in competition to reduce emissions can lower costs. The RFF analysis finds that, "a technology neutral CES coupled with a more stringent target could therefore result in both higher emissions reduction and lower costs relative to a traditional RPS."

The idea of a Clean Energy Standard is not new for this committee. In 2012, Senator Jeff Bingaman introduced the *Clean Energy Standard Act of 2012*. Two years before him, Senator Lindsey Graham sponsored the *Clean Energy Standard Act of 2010*. As states continue to consider the next round of RPS and think about the broader decarbonization challenges for their respective, and shared, electric power sectors, discussion of a national clean energy standard could make sense.

Enhanced Energy Efficiency

Energy efficiency improvements have played an important role in reducing U.S. energy consumption and emissions and increasing energy productivity. Going forward, energy efficiency is estimated to account for well over a third of the cost-efficiency emissions reduction strategies that cut across all aspects of the energy sector. This Committee has worked hard to make sure the often-overlooked focus on energy efficiency is an ongoing priority of the federal government. It goes without saying that efforts to roll back efficiency measures, particularly in the area of vehicle efficiency, threaten to do long-term damage to the competitiveness of U.S. industry. Countries around the world are demanding ever more efficient technologies to help

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[21] National Conference of State Legislatures, "2018 Energy Trends Across State Legislatures," March 2019. http://www.ncsl.org/Portals/1/Documents/energy/2018_energy_trends_33331.pdf

[22] Galen Barbose. "U.S. Renewables Portfolio Standards 2017 Annual Status Report," Lawrence Berkeley National Laboratory. http://eta-publications.lbl.gov/sites/default/files/2017-annual-rps-summary-report.pdf

[23] National Conference of State Legislatures, "State Action in Support of Nuclear Generation," January 26, 2017.

[24] Kathryne Cleary, Karen Palmer, and Kevin Rennert, "Clean Energy Standards," Issue Brief 19-01, Resources for the Future, January 2019. https://www.rff.org/publications/issue-briefs/clean-energy-standards/

curb energy consumption, local pollution concerns, and greenhouse gas emissions. In addition to supporting robust energy efficiency standards in the regulatory process, Congress can continue to fund the energy efficiency research and development priorities at the Department of Energy, supporting regular updates of existing standards, and supporting pilot and demonstration projects for new energy efficiency solutions. In the area of tax policy, tax incentives for energy efficiency measures such as retrofitting existing home and commercial buildings, homeowner purchases of high-efficiency equipment or electric vehicles are all areas to explore. Also, to the extent that this Congress pursues infrastructure related investments, there is an enormous opportunity to embed energy efficient codes and standards, life-cycle cost accounting for projects, and investment in smart energy infrastructure that can increase energy efficiency across a range of sectors.

The fourth and final takeaway for this Committee is that moderate climate policy does not have to be mediocre. These are just two examples of places where moderate federal climate policy could make a difference. They key is to use policy and regulatory mechanisms that people recognize, trust and use, but be ambitious about their targets and implementation. There will be ongoing efforts to build support for economy-wide strategies, which will be necessary to reach deep decarbonization, but these policy pathways, along with others, can play a critical role in making notable progress right now.

Embrace the Green New Deal for what it offers

Finally, a great deal of air time has been given to the House and Senate resolution calling for a Green New Deal (GND). Regardless of one's opinion of that particular approach, the concept provides a number of important elements. First, it is appropriately scaled to the challenge at hand. Second, it strikes the right tone in terms of urgency. Third, it seeks to engage a group of people who feel particularly vulnerable to the changes in our economy and the impacts of climate change. What the plan lacks is a strategy for broad based engagement. As you proceed with your efforts to find bipartisan consensus on a viable and adequate path forward to address climate change, there are many ways to productively work with the sentiments put forth in that resolution. In a previous publication I suggested three:

Make it a rallying cry, not a purity test

Very soon after the GND started attracting attention, a group of environmental organizations submitted a letter outlining the types of energy that would be acceptable under the context of a GND, notably leaving out nuclear and carbon capture and sequestration.[25] They also noted that a carbon tax or cap and trade program should not have a role in the GND policy framework. All of this is unnecessary and counterproductive. For starters, it puts the oil, natural gas, and coal producing communities on the opposing side of this deal from the outset, and if a just transition for those communities is really a priority, they will need to be on board. Moreover, even if supporters of a GND are one hundred percent certain that wind, solar, and hydro are superior low carbon sources of energy, they could be wrong about whether scaling them to 100 percent of the energy system is possible or desirable from a public policy standpoint. Creating this kind of purity text benchmarks on technology or policy solutions will unnecessarily limit the scope of participation and support for the concept. A GND should set outcome related benchmarks about

[25] https://www.eenews.net/assets/2019/01/10/document_daily_02.pdf

greenhouse gas emissions and other factors but avoid being overly prescriptive about the type of solutions that can get us there. The resolution introduced by Senator Markey (D-MA) and Representative Ocasio-Cortez (D-NY) leaves room for debate on these issues, and that will be important.[26]

Expand the base of support and grow potential avenues of execution

The GND resolution is short on details relative to its scope, and that's a good thing because a lot of discussion should still take place. Much of that discussion need not take place only in Washington. Many of the most important policies and regulation affecting the energy sector today happen at the state level. Local and regional discussions about this concept may show areas of agreement or policy approaches that go against the "conventional wisdom" in Washington.

The GND is also, by and large, a platform that speaks in progressive terms. This is fine in principle, but in order to win over non-progressive constituencies, it would be good to articulate its ultimate goals in terms that other political and ideological persuasions can engage. Several pillars of the GND, oftentimes expressed in different terms, can take on centrist and even conservative forms. It is worth noting several recent polls indicate that certain policies designed to address income inequality, such as higher marginal taxes on the wealthy or wage assistance programs, have more support among the general public than previously appreciated. Recognition of the present-day impacts of climate change is also increasing and is likely to only continue to rise in the coming years, and, as a Brookings Institution analysis of Climate Impact Lab data recently pointed out, many of the places hardest hit in the United States are traditionally conservative states.[27] Finally, infrastructure investment is overwhelmingly popular around the country and a huge part of the GND framework.[28] So, while there may be disagreements on the policy mechanisms, many of the plan's pillars already share widespread support. There are many pathways to achieving these goals, and it's worth exploring them in earnest.

Make it a global deal

Many of the issues raised in the GND look like the sustainable and inclusive growth agenda that has emerged in recent years from the International Monetary Fund (IMF). As outlined in a new book by several IMF staff, inclusive growth can occur not at the expense of overall growth, but in support of a more durable kind of economic growth.[29] Many countries around the world could benefit from policies designed to make economies more durable and would pay a negligible or no price for doing so under the right policy design. The GND framework could also spark a much-needed discussion about how to accomplish the goals of decarbonization without harming those who can least afford or would be most impacted by this transition.

Many of the United States' traditional allies and even our strategic competitors, might appreciate U.S. leadership along these lines. Rather than simply looking out for U.S. interests, a global green new deal can be a way for governments to refresh the international system that has brought

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[26] https://assets.documentcloud.org/documents/5729033/Green-New-Deal-FINAL.pdf
[27] https://www.brookings.edu/research/how-the-geography-of-climate-damage-could-make-the-politics-less-polarizing/
[28] https://news.gallup.com/poll/226961/news-public-backs-infrastructure-spending.aspx
[29] https://cup.columbia.edu/book/confronting-inequality/9780231174695

benefits to so many but needs to remedy some of the issues that have gone unaddressed and are at the core of the governance difficulties being faced by many countries. It also provides a new lens through which to discuss the tensions over global competitiveness among countries that have arisen during this period of rapid economic, technological, and geopolitical change.

The most appropriate policy outcomes may differ by country (just as they may differ in the United States by state), but the idea of preparing for and making the transition as part of a new and more durable growth path is a decent starting point for discussion that broadly supports but also potentially reanimates the global discussion regarding sustainable development goals. Which raises the point, why would the GND, if it is just a platform for discussion of ideas, be any more effective than previous discussions on this topic? The answer is, it might not. But, as the world enters the post-post-great recession recovery period and thinks about how to prepare for the inevitable economic challenges of the future, address the populist unrest brought about by economic and social anxiety, and take a more ambitious posture vis-à-vis the global climate crisis, it provides the component pieces of a path forward.

The CHAIRMAN. Thank you, Ms. Ladislaw.

Mr. Sandalow, welcome.

STATEMENT OF HON. DAVID B. SANDALOW, INAUGURAL FELLOW, SIPA CENTER ON GLOBAL ENERGY POLICY, COLUMBIA UNIVERSITY

Mr. SANDALOW. Thank you, Chairman Murkowski, Ranking Member Manchin and all members of the Committee on Energy for the opportunity to testify today.

I've been privileged to appear here several times before, and I've observed your long tradition of constructive, bipartisan dialogue.

I've worked on the topic of today's hearing, energy innovation and climate change, for many years on the White House staff, as an Assistant Secretary of State, as an Assistant Secretary of Energy and as Acting Under Secretary of Energy. Today I'm honored to be the Inaugural Fellow at Columbia University Center for Global Energy Policy.

My testimony today will have three core points.

First, energy innovation is central for fighting climate change. In the past decade dramatic innovations have begun to change the energy sector. Solar and wind power costs have fallen dramatically, for example, but more is needed. To help cut carbon emissions at the speed required in the decades ahead, we'll need innovation in many areas. The highest priorities, in my view, include energy storage, floating offshore wind, industrial heat, heavy duty road transport, aviation, carbon capture, utilization and storage including direct air capture of carbon dioxide and cheap, passably safe nuclear reactors. I discuss each of these areas in more detail in my written testimony which is submitted for the record.

My second and perhaps most important point is that innovation alone won't solve climate change. Innovation is essential for fighting climate change, but it's not enough. The most innovative low-carbon technologies won't help fight climate change unless they're deployed, and widespread deployment of low-carbon technologies often requires a range of policies. The building sector offers a classic example. Many simple technologies for improving the energy efficiency of buildings are readily available, but they sit unused due to features of the real estate market. Policies such as building codes and appliance standards are necessary.

More broadly, access to low cost capital is especially important for moving innovative technologies to market. Historically, this has been a significant challenge for low-carbon technologies and without government programs to reduce capital costs, many innovative low-carbon technologies will never make it to market. Removing subsidies enjoyed by fossil fuel technologies so that low-carbon technologies can compete on a level playing field is an especially important tool for moving innovative low-carbon technologies from the lab to market. And finally, global engagement is essential for solving climate change. Policies to promote the global deployment of low-carbon technologies are essential.

My third core point is that as a nation we should build on our strengths and address our weaknesses when it comes to energy innovation. The United States has an extraordinary record when it comes to energy innovation. And Madam Chairman, as you said,

our strengths include our great universities, our national lab system and our entrepreneurial culture.

At the same time, I believe we have weaknesses that inhibit our ability to promote energy innovation. One is our broken politics. You know, U.S. politics has always been rough, but in recent years polarization has been especially extreme. A second weakness is a lack of respect for science. It's ironic that in a nation with such extraordinary universities and national labs, the envy of much of the world, science receives such little respect. Top leaders and significant minorities of the public reject scientific conclusions on topics as wide-ranging as climate change and vaccinations. In my travels in Asia and Europe, I often encounter people who are deeply puzzled by this phenomenon. And a third weakness I would point to is our short-term focus both in government and in many parts of the investment community.

So, what can we do to build on our strengths and address our weaknesses? Step one, increase federal budgets for energy innovation and I applaud Senator Alexander's call to double federal funding for clean energy innovation. Second, channel U.S. entrepreneurial spirit toward meeting the climate challenge. Policies that improve the returns that businesses earn from deploying innovative energy technologies are essential, that could include tax credits, performance standards, eliminating fossil fuel subsidies and a price on carbon. Third, build long-term thinking into federal decision-making on energy innovation with multiyear planning processes and investors focusing long-time horizons on their investments.

So my testimony today has had three core points. First, energy innovation is essential for fighting climate change. Second, innovation alone won't solve climate change. And third, as a nation we should build on our strengths and weaknesses when it comes to energy innovation.

Thanks for the opportunity to testify. I look forward to answering your questions.

[The prepared statement of Mr. Sandalow follows:]

COLUMBIA | SIPA
Center on Global Energy Policy

Statement of the
Honorable David B. Sandalow

before the
Committee on Energy and Natural Resources
United States Senate
April 11, 2019

Chairman Murkowski, Ranking Member Manchin and Members of the Senate Committee on Energy and Natural Resources --

Thank you for the opportunity to appear before you to discuss energy innovation and other potential solutions to help address climate change. It's an honor to return to the Committee. I've appeared here several times before to discuss electric vehicles, clean energy standards and other topics. Over the years I've observed the Committee's long tradition of constructive bipartisan dialogue. I wish you every success in continuing that tradition in the months and years ahead.

I have worked on energy innovation and climate change for many years -- as a member of the White House staff, an Assistant Secretary of State, an Assistant Secretary of Energy and Acting Under Secretary of Energy. Today I'm honored to be the Inaugural Fellow at the SIPA Center on Global Energy Policy at Columbia University. Our mission is to help public and private sector leaders as they make choices about the world's most pressing energy issues. I hope to be able to do that with today's testimony.

My testimony today will have four core points:

- First -- energy innovation is essential for fighting climate change.
- Second -- some energy innovations fight climate change. Some don't.
- Third – innovation alone won't solve climate change
- Fourth – as a nation, we should build on our strengths and address our weaknesses when it comes to energy innovation.

I'll discuss each of these in turn.

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Center on Global Energy Policy

***First -- energy innovation is essential for fighting climate change*.**

The energy sector (including power, transport, heating and more) produces roughly 75% of global greenhouse gas emissions. Significant reductions in energy sector emissions are essential in addressing climate change.

In the past decade, dramatic innovations have begun to change the energy sector, offering great promise in responding to climate change. Solar module costs have fallen by more than 80% since 2010. Wind turbine costs have fallen by half during the same period, with taller towers and larger blades greatly improving the ability to generate power from wind.

From Indiana to India, solar and wind power are now competing on the basis of cost with coal-fired power. Last year the Northern Indiana Public Service Co. found it could save customers more than $4 billion over 30 years by replacing its coal-fired power with solar power, wind power, energy storage and demand response. In 2016, Indian Energy Minister Piyush Goyal said "a new coal plant would give you costlier power than a solar plant" in India.

But more is needed. The scientific consensus is clear: the impacts of climate change are already here, and we must cut carbon emissions deeply in the decades ahead to avoid risk of catastrophic damages. The Paris Agreement, ratified by more than 180 nations, calls for net zero greenhouse gas emissions by the second half of this century. To reach safe levels of emissions, we will need energy innovation in many areas. The highest priorities include:

- **Energy storage.** Battery costs have fallen significantly in recent years. But further reductions in energy storage costs are needed for deep decarbonization of both the transport and power sectors. Vehicle electrification will proceed much more quickly once the purchase price of an electric vehicle is less than the purchase price of a comparable conventional vehicle. (Many experts believe that will happen by the mid-2020s.) Cheap large-scale, long-duration energy storage would make an enormous difference in integrating high volumes of solar and wind power into electric grids.
- **Floating offshore wind.** Offshore wind power costs have declined significantly in recent years. Here too more is needed. Cost-competitive floating offshore wind technology could dramatically expand areas available for production of wind power.
- **Industrial heat.** High temperatures are essential for the manufacture of many products including iron and steel, chemicals and cement. Today almost all that heat is generated from the combustion of fossil fuels – leading to roughly 15% of global emissions.

Finding ways to generate high temperatures for industrial purposes without greenhouse emissions is essential for deep decarbonization.

- **Heavy-duty road transport.** Trucks, buses and other heavy duty on-road vehicles are responsible for roughly 5% of global greenhouse gas emissions. Municipal bus fleets are starting to convert to electric drive trains (with more than 400,000 electric buses already on the roads in China), but decarbonization of long-haul transport may require innovations in hydrogen fuel cells and/or renewable liquid fuels.
- **Aviation.** Aviation is responsible for roughly 2% of global greenhouse gas emissions and growing fast. Powering most airplanes with electric motors and batteries is not possible with today's technology. Biofuels are a potential pathway for decarbonizing aviation, but building biofuel supply chains with net zero emissions at a scale sufficient for the global aviation industry will require innovation. Improvements in air traffic management could help reduce emissions growth in this sector.
- **Carbon capture, utilization and storage.** Carbon dioxide (CO_2) is currently being separated from the flue gas of coal-fired power plants and industrial facilities at several dozen sites around the world. CO_2 is being separated from the ambient air at several sites as well. Carbon capture technologies, when coupled with technologies that convert CO_2 into commercially useful products or permanently sequester CO_2 underground, have enormous potential to contribute to solutions to climate change. Innovations are needed to drive down the costs and improve performance of these technologies.
- **Cheap, passively safe nuclear reactors.** Nuclear energy provides more than half of the United States' carbon-free energy. However many reactors are nearing the end of their useful lives, even with life extensions. Replacing those reactors with new ones could help prevent emissions increases once those plants retire, however new nuclear power plants face at least two significant barriers: cost and public acceptance. Innovations to reduce the costs of new nuclear reactors while addressing public concerns (in part by ensuring that operator intervention is not needed for a safe shutdown) could make an enormous difference in fighting climate change.

Second -- some energy innovations fight climate change. Some don't.

Not all energy innovations help fight climate change.

For example, in recent decades advances in 3-D seismic, tension-leg platform and other technologies have dramatically enhanced the ability to produce oil from the deep ocean. Forty years ago, no oil rig in the Gulf of Mexico operated in water deeper than 2,000 feet. Today rigs can operate in 12,000 feet of water. The expansion of oil drilling into ultra-deep waters is the result of significant technological innovations. However those innovations do not contribute to the fight against climate change.

Another example: autonomous vehicles. The potential climate impacts of autonomous vehicles are quite uncertain:

- Autonomous vehicle technology could increase greenhouse gas emissions by lowering barriers to driving and increasing vehicle miles traveled.
- Autonomous vehicle technology could reduce greenhouse gas emissions by improving driving efficiency, facilitating vehicle platooning and reducing miles spent looking for parking spaces in urban areas.

Autonomous vehicles are hugely important innovations, with potentially far-reaching consequences, however on their own they do not necessarily contribute to the fight against climate change. Policies promoting the coupling of autonomous vehicle technology with electric drive trains may be essential to ensure that autonomous vehicles do not increase emissions.

Third -- innovation alone won't solve climate change.

Innovation is essential for fighting climate change. But it's not enough. The most innovative, low-carbon technologies won't help fight climate change unless they're deployed. And widespread deployment of low-carbon technologies often requires a range of policies.

The building sector offers a classic example. Many simple technologies for improving the energy efficiency of buildings are available but sit unused due to a combination of factors including split incentives between landlords and tenants, lack of information among architects and builders, and inattention to energy costs by buyers at the time of purchase. Policies such

as building codes and appliance efficiency standards can make a big difference in saving energy, cutting costs and reducing emissions.

Access to low-cost capital is especially important for innovative technologies to reach the market at scale. Historically this has been a significant challenge for many low-carbon technologies due to the amounts of capital needed, timeframes in which returns can be expected and risk aversion of debt markets. Without government intervention to guarantee loans, cover first loss risks or otherwise reduce capital costs, many innovative low-carbon technologies will never make it from the lab to marketplace. The growth of utility-scale solar power in the United States offers an example of the benefits of such tools.

A price on carbon offers an especially powerful tool for moving innovative low-carbon technologies from the lab to marketplace. Technologies that emit greenhouse gases receive an implicit subsidy when they are allowed to do so – imposing costs on others -- at no charge. (The IMF has estimated the value of this subsidy at more than $1 trillion globally.) Correcting this imbalance would make a big difference in addressing climate change. This can be done while promoting economic growth and putting more money in the pockets of most American taxpayers.

Finally, global engagement is also essential for solving climate change. Although the United States is the world's second largest emitter, and responsible for more greenhouse gases in the atmosphere than any other nation, last year the vast majority of global emissions came from outside our borders. Policies to promote the global deployment of low-carbon technologies are essential to meeting the challenge of climate change.

There is a virtuous cycle to many of the policies discussed above. These policies are essential complements to the innovation agenda. Without such policies, technological innovation will not provide climate solutions at the scale and speed needed. At the same time, many of these policies also promote innovation as one of their core features:

- Building codes that set performance standards for energy use per square foot encourage innovations in building energy efficiency.
- Loan guarantees that help an industry scale help drive down technology costs.
- A price on carbon encourages innovation in low-carbon technologies across the entire economy.

- Policies to promote global deployment of low-carbon technologies help those technologies scale, driving down costs.

Policies essential for innovative, low-carbon technologies to deliver real climate solutions often promote innovation as well.

Fourth – as a nation, we should build on our strengths and address our weaknesses when it comes to energy innovation.

The United States has an extraordinary record when it comes to energy innovation. Our universities, national labs, companies and others have played central roles in the development of solar power, wind power, energy storage, hydraulic fracturing, horizontal drilling, nuclear power, building energy efficiency technologies and much more. However that record of success does not guarantee future results. To retain our abilities and pre-eminence, we must regularly assess our strengths and weaknesses. We should build on the former and address the latter.

Three strengths stand out:

- *Our great universities*. The United States has an extraordinary system of higher education, with dozens of pre-eminent universities filled with superb research talent. Top students from around the world dream of coming to U.S. universities to study. The research and training underway in our universities provide an essential foundation for our nation's work on energy innovation.
- *Our national lab system.* U.S. Energy Secretary Rick Perry has called DOE's 17 national laboratories "the crown jewels of American science." These national labs are an extraordinary resource, with some of the world's best scientists, fastest computers and well-designed facilities for promoting energy innovation.
- *Our entrepreneurial culture.* We are a nation of strivers. We respect those who take risks to deliver results. From the earliest days of our republic, we have applauded and rewarded those who innovate in business and a range of endeavors.

At the same time, three weaknesses inhibit our ability to promote energy innovation:

- *Our broken politics.* US politics has always been rough. But in recent years polarization has become especially extreme. A former Senator told me recently how much less civil

this body is now than when he first knew it. That interferes with the ability to generate consensus around programs and policies that should command broad support. It creates risks that programs will be attacked due to their political sponsorship more than their potential or results.

- *Lack of respect for science.* It is ironic that, in a nation with such extraordinary universities and national laboratories, the envy of much of the world, science receives such little respect. Top leaders and significant minorities of the public reject scientific conclusions on topics as wide-ranging as climate change and vaccinations. In my travels in Asia and Europe I often encounter people deeply puzzled by this phenomenon. This undercuts political support for the work needed to promote energy innovation.
- *Short-term focus.* Several European governments set energy and emissions targets 10-15 years ahead and then adjust policies to implement those targets year after year. The Chinese government develops Five-Year Plans with energy and emissions targets that guide policymakers in the central government and provinces. In the United States, we struggle to pass one-year appropriations bills. I would not trade our governance system for that of any other nation, but we could learn a great deal from other countries about planning. In addition -- the payback period for many clean energy innovations is beyond the time horizons of many investors. That has limited access to capital in the sector.

What can we do to build on our strengths and address our weaknesses? That's a large topic, with many answers. I'll briefly suggest three steps:

- *Increase federal budgets for energy innovation.* For generations, U.S. government funding has played a central role in world-changing innovations. Among the innovations that grew directly from federal funding are the Internet, the Google search engine, GPS devices, DNA mapping, inexpensive mass data storage and even Teflon. Federal funding has played an important role in many energy innovations including solar power, wind power, hydraulic fracturing, horizontal drilling and nuclear power.

  Within the federal government, the U.S. Department of Energy plays an especially important role in energy innovation. The Office of Science, ARPA-E, the Office of Energy Efficiency and Renewable Energy, the Office of Fossil Energy, the Office of Nuclear Energy and other offices conduct vitally important research on energy technologies. These offices support work throughout the national lab system and in universities around the country. Their capacity to deliver results for the nation far exceeds their budgets.

The budgets for DOE and other federal offices that support energy innovation need substantial increases in the years ahead. I applaud Senator Lamar Alexander's call to double federal funding for clean energy research as part of his recent New Manhattan Project for Clean Energy.

- *Channel U.S. entrepreneurial spirit toward meeting the climate challenge.* Federal R&D spending for energy innovation is important. But most R&D in the United States is funded by the private sector. Most energy technologies in the United States are deployed by the private sector. The private sector is a powerful engine of progress.

  Policies that improve the returns businesses earn from deploying innovative energy technologies are among the most powerful tools available for promoting energy innovation. There are many examples, including tax credits (which have helped accelerate innovation in solar power, wind power, electric vehicles and carbon capture, use and storage) and performance standards (such as the renewable portfolio standards in effect in 29 states, which have helped accelerate innovation in solar and wind power). A federal carbon price or clean energy standard would each be powerful tools for accelerating clean energy innovation.

  Harnessing the power of the private sector to promote energy innovation is especially important for climate solutions.

- *Build long-term thinking into decision-making on energy innovation.* DOE should launch multi-year, multi-stakeholder planning processes with respect to clean energy innovation. Working with other federal agencies, national labs, universities, businesses and others, DOE should identify clean energy innovation goals, barriers to achieving to them and strategies for overcoming those barriers. In addition – building on the example of the Breakthrough Energy Coalition, institutional investors, philanthropies and other capital providers with long time horizons should increase their support for promising clean energy innovations.

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My testimony today has had four core points:

- First -- energy innovation is essential for fighting climate change.
- Second -- some energy innovations fight climate change. Some don't.
- Third – innovation alone won't solve climate change
- Fourth – as a nation, we should build on our strengths and address our weaknesses when it comes to energy innovation.

Chairman Murkowski, Ranking Member Manchin and Members of the Senate Committee on Energy and Natural Resources, thank you for the opportunity to appear before you. I look forward to your questions.

The CHAIRMAN. Thank you, Mr. Sandalow.

Mr. Bryce, welcome.

STATEMENT OF ROBERT BRYCE, SENIOR FELLOW, MANHATTAN INSTITUTE

Mr. BRYCE. Good morning.

Electricity is the world's most important and fastest growing form of energy. The electricity sector is also the biggest single contributor to global greenhouse gas emissions. My third point, that right now at current rates of growth, about four percent per year, global electricity demand will grow and it will rather double in just 18 years. So given those facts what should we do?

Well, first of all we cannot rely on renewables alone. Numerous environmental groups and politicians are pushing for all renewable energy systems, but the hard truth is that these 100 percent renewable energy scenarios are nothing more than politically popular distractions. These scenarios are neither doable nor desirable. These scenarios ignore basic math and simple physics. Worse yet, they perpetuate what I call, the "vacant land myth," the idea that there's endless amounts of land out there in flyover country that's just waiting for all kinds of renewable energy infrastructure to be built on top of it. Nothing could be further from the truth.

By my count, since 2015 some 225 government entities from New York to California have moved to reject or restrict wind energy projects. New York has a 50 percent renewable electricity mandate by 2030 but dozens of local governments in New York have either passed measures restricting or outright rejecting wind energy projects.

You won't read about this in the New York Times, but the towns of Yates and Somerset as well as three upstate New York counties, Erie, Orleans and Niagara, have spent the last three years fighting a proposed 200-megawatt lighthouse wind project which aims to put dozens of wind turbines near the shores of Lake Ontario. New York's offshore wind plans are being vigorously opposed by the state's commercial fishing groups.

California has a 60 percent renewable electricity mandate by 2030, but in 2015 the Los Angeles County Board of Supervisors banned wind projects in the county. In February of this year, San Bernardino County, the largest county by area in America, banned large scale renewable projects throughout much of the country. San Bernardino County is the home to two of the largest thermal solar projects in America, Abengoa Mojave and Ivanpah. Today California has less installed wind capacity than it did in 2013.

Last year high voltage transmission projects designed to transport renewable energy across New Hampshire and Arkansas were both canceled due to state-level opposition.

In short, renewable energy alone cannot provide the vast scale of energy that the U.S. and global economies demand at prices consumers can afford.

So what is the best approach? In my view, it is N2N, natural gas to nuclear. These sources provide the best, no regret strategy because they are low-carbon, scalable, and affordable.

Thanks to innovations in the shale revolution, the U.S. has become the world's biggest and most important natural gas producer.

Natural gas helps reduce or helps decarbonization, because it emits half as much CO_2 during combustion as coal and about a third less than fuel oil or diesel fuel.

Natural gas has helped cut U.S. CO_2 emissions which in 2017 were at their lowest level since 1992. Last year the U.S. exported LNG to 30 different countries including Kuwait and the United Arab Emirates. It's an open secret in Houston that Saudi Arabia is now seeking a long-term LNG supply contract with American companies.

What does the U.S. natural gas sector need in terms of federal policy? In my view, nothing. Where federal policymaking is needed and needed in a big way is in the nuclear energy sector. There is no credible pathway toward widespread, large-scale decarbonization that doesn't include large increments of new nuclear capacity.

Congress should develop a strategy that includes preserving existing plants and nurturing the development and commercial deployment of the next generation of smaller, safer, cheaper reactors. The Federal Government should support nuclear energy because it is emissions free, has extraordinarily high-power density, meaning it requires very little land, and it helps diversify the electric grid.

Let me be clear, the nuclear industry faces myriad challenges, opposition from some of the biggest environmental groups in America including Sierra Club and the Natural Resources Defense Council are among them. Many existing reactors cannot operate at a profit. New reactors cost way too much and, of course, Congress continues to doddle when it comes to the issue of nuclear waste storage and disposal.

But I will reiterate my point. There is no reasonable or affordable pathway to decarbonization of the electric sector here in the United States or around the world that does not include big chunks of new nuclear capacity. If Congress wants to foster innovation in nuclear energy, Republicans and Democrats will have to forge significant, long-term, and by that I mean decadal, commitments toward making that goal a reality.

Thank you.

[The prepared statement of Mr. Bryce follows:]

9 April 2019

Statement to Senate Energy and Natural Resources Committee

Hearing regarding energy innovation and other potential solutions to help address global climate change.

April 11, 2019

Robert Bryce

Senior fellow, Manhattan Institute
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Serious discussions about climate change must focus intently on the global electricity sector. There are three reasons for that.

Electricity is the world's most important and fastest-growing form of energy.[1]

Electricity production accounts for the biggest single share of global carbon-dioxide emissions: about 25 percent.[2]

Third, regardless of what happens in the future –whether the global climate gets hotter, cooler, or more extreme – we are going to need vastly more electricity than what is currently being consumed around the globe. In 2018, global electricity use jumped by 4 percent.[3] At that rate of growth, global electricity use will double in just 18 years.

Given those facts, innovation in all facets of the electricity sector – from generation and transmission to storage and end-use efficiency – can help in efforts to decarbonize the global economy. I will address two questions: which low-carbon electricity-generation technologies can be deployed at significant scale and in doing so, foster decarbonization in the electricity sector? Second, what should the government be doing to foster innovation in those technologies?

I will address those questions by making two points. First, we can't rely on renewables alone. Second, I will explain why natural gas to nuclear energy (what I call N2N) offers the best no-regrets strategy.[4] Natural gas and nuclear are low-

carbon, scalable, and affordable. Those attributes make them essential to any large-scale decarbonization strategy.

Renewables Aren't Enough

Before going further, let me be clear: I am not opposed to renewables. I have 8.5 kilowatts solar panels on the roof of my house in Austin, Texas.

Further, it's obvious that renewable energy is growing rapidly. In fact, I have seen firsthand how renewables are competing with traditional forms of generation. In 2017, while I was in Lebanon shooting video for my upcoming documentary, *Juice: How Electricity Explains the World*, I visited Bkerzay, a resort in the Chouf Mountains that is relying solely on solar energy. That facility is using lead-acid batteries (with a total capacity of 300 kilowatt-hours) to store electricity produced by 100 kilowatts of solar panels. That system provided all of the electricity used by the resort, including the restaurant, ceramics studio, and guest rooms.

The growth of renewables – and solar energy in particular – is impressive.[5] That growth is being touted by numerous environmental groups and politicians who are pushing for policies that would require our energy and power systems to rely solely on renewable energy. For instance, in early 2019, some 600 environmental groups submitted a letter to the US House of Representatives which said that the US must shift to "100 percent renewable power generation by 2035 or earlier." The same letter said that any "definition of renewable energy must…exclude all combustion-based power generation, nuclear, biomass energy, large-scale hydro, and waste-to-energy technologies." It continued, saying that the new electric grid must have the "ability to incorporate battery storage and distributed energy systems that are democratically governed." Signers of the letter included groups like Food & Water Watch, Friends of the Earth, and the Environmental Working Group.[6]

The notion of all-renewable energy and power systems may be political popular, but the simple truth is that 100-percent renewable scenarios are neither doable nor desirable.

Over the past few years, all-renewable scenarios have been put forward by various groups and academics. Perhaps the most famous of those scenarios was published by Stanford professor Mark Jacobson. In 2015, Jacobson published a paper, co-written with Mark Delucchi, a research engineer at the University of California-Berkeley, in the *Proceedings of the National Academy of Sciences*. The paper, which claimed to offer "a low-cost solution to the grid reliability problem" with

100-percent renewables, went on to win the Cozzarelli Prize, an annual award handed out by the National Academy of Sciences. A Stanford web site said that Jacobson's paper was one of six chosen by "the editorial board of the *Proceedings of the National Academy of Sciences* from the more than 3,000 research articles published in the journal in 2015."[7]

But a 2017 paper published in the *Proceedings of the National Academy of Science* by a group of prominent American scientists led by Chris Clack – a mathematician who has held positions at the National Oceanic and Atmospheric Administration and the University of Colorado – thoroughly debunked Jacobson's claims than an all-renewable energy economy was feasible or affordable. Clack and his co-authors, who included Dan Kammen of the University of California-Berkeley, former EPA Science Advisory Board Chair Granger Morgan, and Jane Long of Lawrence Livermore National Laboratory, concluded that Jacobson's work contained "numerous shortcomings and errors." The paper also used "invalid modeling tools, contained modeling errors, and made implausible and inadequately supported assumptions." Those errors, "render it unreliable as a guide about the likely cost, technical reliability, or feasibility of a 100-percent wind, solar, and hydroelectric power system."

Clack and his colleagues also found that to accommodate all of the wind turbines needed to achieve Jacobson's all-renewable vision would require "nearly 500,000 square kilometers, which is roughly 6 percent of the continental United States and more than 1,500 square meters of land for wind turbines for each American."[8]

Clack's paper underscored the fundamental problem with large-scale renewable deployment: it simply requires too much land.

All-renewable scenarios rely on the vacant-land myth – the faulty notion that there's endless amounts of unused, uncared-for land out there in flyover county that's ready and waiting to be covered with forests of renewable-energy stuff. The truth is quite different. Rural communities – even entire states – are resisting or rejecting wind, solar, and high-voltage transmission projects and that opposition is already slowing deployment of new renewable capacity in the US, Canada, and Europe.

Energy policy and land-use policy are inextricable. Proof of that can be seen by looking at the protests over the Keystone XL and Dakota Access pipelines. Climate-change activists are increasingly targeting pipeline projects as a way to rally public sentiment toward their cause. Those high-profile battles have received

widespread media coverage. By contrast, national media coverage of the growing backlash against deployment of large-scale renewable-energy projects has been scant. That lack of media coverage is particularly true when it comes to controversies about wind-energy deployment.

Since 2015, I have been tracking rural opposition to wind energy projects. By my count, some 225 government entities from New York to California have moved to restrict or reject wind projects.

In New York, Gov. Andrew Cuomo has mandated that the state be obtaining 50 percent of its electricity from renewables by 2030.[9] Despite the mandate, by my count, about four dozen local governments in New York have passed measures restricting or prohibiting wind energy projects.

You won't read about it in the *New York Times*, but the towns of Yates and Somerset as well as three upstate New York counties – Erie, Orleans, and Niagara – have spent the past three years fighting the proposed 200-megawatt Lighthouse Wind project, which aims to put dozens of wind turbines near the shores of Lake Ontario.

Now, let's look at California, which has a 60-percent renewable electricity mandate by 2030.[10]

In 2015, the Los Angeles County Board of Supervisors voted unanimously in favor of an ordinance banning large wind turbines in the county's unincorporated areas.[11] During a hearing on the measure, then-Supervisor Michael D. Antonovich said "Wind turbines create visual blight." In addition, he said the skyscraper-sized turbines would "contradict the county's rural dark skies ordinance which aims to protect dark skies in areas like Antelope Valley and the Santa Monica Mountains."[12]

In February of this year, San Bernadino County, banned large-scale renewable projects throughout much of the county. San Bernadino County covers more than 20,000 square miles and is the largest county, by land area, in the country.[13] It's already home to two big thermal-solar projects, including Ivanpah and Abengoa Mojave.[14] The county's new regulations prohibit construction of new large-scale projects if more than half of the energy produced from them is to be exported out of the county.[15]

Building new wind projects in California is so difficult that the wind industry has nearly given up trying to site any new turbines in the state.[16] According to the California Wind Energy Association, the state now has about 5,535 megawatts of installed wind capacity.[17] That's *about 250 megawatts less* than what the state had back in 2013.[18]

In Oklahoma, the town of Hinton, (population: 3,200) spent about two years fighting the world's biggest wind-energy producer, NextEra Energy. In January 2017, the town passed an ordinance that prohibited the construction of wind turbines within two miles of its borders. The following month, the Florida-based company sued the town of Hinton in both federal and state courts. In a 2018 phone interview, Mayor Shelly Newton told me that Hinton officials passed the measure in 2017 because "We were trying to give ourselves some elbow room."

Earlier this week, I spoke to Mayor Newton again. She explained that the town beat NextEra in court and that the company reimbursed the town for its legal expenses. When I asked why the town fought the company and its proposed wind project, she replied, "These aren't wind farms. They are industrial wind complexes that would change our agricultural land into an industrial area. We don't want to live in an industrial wind complex. And we didn't want it forced on us." She continued, "These are not wind farms. It has nothing to do with agriculture."[19]

In Henry County, Indiana, seven communities have passed resolutions establishing a four-mile buffer zone around their towns. In a November 1, 2018 article titled "County Towns Putting Up Walls Against Wind," Darrel Radford, a reporter for the *New Castle Courier-Times* wrote that "there's still lots of anti-turbine activity" in the county and that "as many as half" of the incorporated communities in Henry County had passed anti-wind measures.[20]

Looking north of the US border, Ontario has been a hotbed of anti-wind activism. In that Canadian province, 90 towns have declared themselves "unwilling hosts" to wind projects.[21]

The anti-wind backlash is also obvious across the Atlantic. In 2010, the European Platform Against Windfarms had about 400 members in 20 countries. By 2018, it had nearly quadrupled in size and counted some 1,400 member organizations in 32 countries.[22]

The backlash is particularly apparent in the German state of Bavaria as well as in Poland. Both places have effectively banned wind turbines by implementing the

so-called 10-H rule, which requires turbines be located no closer than 10 times their height from the nearest homes or other sensitive areas.[23]

In 2016, a wind project near Scotland's famous Loch Ness was rejected by local authorities because of its potential impact on tourism.[24] Scotland Against Spin, a coalition of environmental groups that is fighting wind energy projects in that country says on its website that it is "against the spin of the turbines, the spin of the developers and their lobbyists, and the spin of the Government."[25]

It's not just wind projects.

Residents of Spotsylvania County, Virginia are fighting a proposed 500-megawatt solar project that, if built, would cover nearly 10 square miles. According to the Fredericksburg *Free Lance-Star*, local residents are opposed because they believe the solar project "is too big to be near homes and that it poses potential health and environmental risks. They also are concerned about impacts to property values."[26]

In Charles County, Maryland, environmental groups are fighting a solar-energy project backed by Georgetown University. The project would require clear-cutting 240 acres of forest that, according to the *Baltimore Sun*, is among fewer "than three dozen areas in Maryland that the Audubon Society has deemed an 'important bird area,'" meaning it is a rare remnant of large contiguous forest land. A member of the Southern Maryland chapter of the Sierra Club called the solar project "thoughtless of the future."[27]

High-voltage transmission projects are also facing opposition.

In 2017, Iowa enacted a law which prohibits the use of eminent domain for high-voltage transmission lines. The move doomed the Rock Island Clean Line, a 500-mile, $2 billion, high-voltage direct-current transmission line that was going to carry electricity from Iowa to Illinois.[28]

In early 2018, Houston-based Clean Line Energy Partners suspended its years-long effort to build a 720-mile, $2.5 billion transmission line across the state of Arkansas. The Plains & Eastern Line aimed to carry wind energy from Oklahoma to customers in the southern and southeastern US. But the project faced fierce opposition in Arkansas where the state's entire Congressional delegation opposed the deal.[29]

Also in 2018, New Hampshire regulators rejected a high-voltage electricity

transmission project called Northern Pass Transmission that was to carry power from Quebec hydroelectric facilities to consumers in Massachusetts. But the 192-mile, $1.6 billion project – which was to go through New Hampshire's White Mountains – was vetoed in a unanimous vote by the New Hampshire Site Evaluation Committee.[30]

Renewable energy's land-use problem is directly related to the issue of scale. If we are to dramatically increase the use of wind energy, it will require dramatic increases in the amount of land dedicated to that purpose. That was made clear by author Vaclav Smil in his 2010 book, *Energy Myths and Realities: Bringing Science to the Energy Policy Debate.* Smil wrote that relying on wind turbines to supply all US electricity would "require installing about 1.8 terawatts of new generating capacity," which he explained, "would require 900,000 square kilometers of land."[31] For perspective, that's a land area twice the size of the state of California.[32]

In addition to the land-use problem, renewable sources are not scaling fast enough. In fact, renewables cannot even keep pace with the growth in global energy demand. That can be seen by looking at the March 26 report from the International Energy Agency which found that in 2018, "Demand for all fuels rose, with fossil fuels meeting nearly 70 percent of the growth for the second year running. Renewables grew at double-digit pace, but still not fast enough to meet the increase in demand for electricity around the world."[33]

The IEA also reported that global natural gas use in 2018 increased by 4.6 percent.[34] To put that in context, the growth in global gas use last year was about 2.9 million barrels of oil equivalent. Therefore, *merely the increase* in global gas use in 2018 *was greater than the output of all global solar projects*. (In 2017, all global solar production totaled about 2 million barrels of oil equivalent.[35])

Natural gas can help decarbonization

Natural gas is the cleanest of the hydrocarbons and therefore it can help reduce the growth of global carbon dioxide emissions. The reasons for this: gas is scalable, relatively low-carbon, and it can be used to replace coal in the electricity sector and oil in the transportation sector.

Substituting gas for those fuels helps reduce greenhouse gas emissions. During combustion, gas produces about half as much carbon dioxide as coal and about 30 percent less than diesel fuel or fuel oil.[36]

Much of the growth in global natural gas production is due to a string of innovations that have occurred here in the United States. Thanks to the shale revolution, which combines innovations in horizontal drilling, hydraulic fracturing, and related technologies, the US has become the world's biggest and most important gas producer. Indeed, the growth in domestic gas production has been nothing short of astonishing. In 2005, US gas production was about 47 billion cubic feet per day. This year, US gas production will average about 90 billion cubic feet per day.[37] That's an increase of 91 percent, or 43 billion cubic feet per day, in just 14 years.

To put that in perspective, consider this: since 2005, *just the increase* in US natural gas production is equal to two times Iran's entire natural gas production.[38] It's also equal to four times Saudi Arabia's natural gas production.[39]

The surge in shale-gas production has transformed both the domestic and international gas businesses. Domestically, coal-fired power plants are being rapidly replaced by gas-fired ones. Between 2000 and 2017, the amount of US electricity generated by gas-fired power plants more than doubled while the amount of juice produced from coal fell by nearly 40 percent. The substitution of gas for coal in the electricity sector helps explain why US carbon-dioxide emissions in 2017 were the lowest they have been since 1992.[40]

The shale revolution has made the US a pivotal player in the global liquefied natural gas business. At the end of 2018, the US was exporting about 4 billion cubic feet of LNG per day. Only Australia and Qatar currently have more LNG export capacity than the US, and if all of the planned LNG facilities are approved, the US will soon be the world's biggest LNG exporter.[41] By mid-2020, the Energy Information Administration expects US LNG export capacity will reach 10.6 billion cubic feet per day.[42] Thus, within a year or so, US LNG exports could be nearly equivalent to the entire gas output of Norway, Europe's biggest gas producer.[43]

In 2018, the US exported LNG to 30 different countries, including Kuwait and the United Arab Emirates, both of which are major oil producers.[44] Furthermore, it's an open secret in Houston that Saudi Arabia, the world's biggest oil producer, is now trying to secure a long-term LNG contract with US suppliers. Doing so would allow the Saudis to reduce the amount of oil they are using to generate electricity and replace it with lower-cost LNG from the US.

What does the natural gas sector need in the way of federal policy? In my view, the industry doesn't need much at all. It has accomplished meteoric growth over the past decade without much government intervention. Thus, a federal policy of benign neglect would be the best.

That is not the case for nuclear energy.

Nuclear energy is essential to decarbonization

There is no credible pathway toward decarbonization that doesn't include nuclear energy. That is the consensus among the world's top climate scientists and energy analysts.

In 2013, James Hansen and three other climate scientists wrote an open letter to environmental groups encouraging them to support nuclear. They wrote that "continued opposition to nuclear power threatens humanity's ability to avoid dangerous climate change…Renewables like wind and solar and biomass will certainly play roles in a future energy economy, but those energy sources cannot scale up fast enough to deliver cheap and reliable power at the scale the global economy requires."[45]

In 2015, the International Energy Agency declared that "Nuclear power is a critical element in limiting greenhouse gas emissions."[46] It went on, saying that global nuclear generation capacity, which in 2018 totaled about 375 gigawatts, must more than double by 2050 if the countries of the world are to have any hope of limiting temperature increases to the 2-degree scenario that is widely agreed as the acceptable limit.[47]

In 2018, a study published by the MIT Energy Initiative concluded that attempting to decarbonize electricity production with renewables alone would cost 2 to 4 times as much as one that included nuclear energy.[48]

Given nuclear's essential role in decarbonization, what should the federal government be doing when it comes to fostering innovation in the nuclear energy sector? Put short, Congress should develop a strategy on nuclear energy that includes preserving existing plants and nurturing the development and deployment of new, safer, cheaper, reactors that can be used in the electricity grids of the future.

Nuclear energy should be getting federal support due to its advantages over other forms of electricity production. Among those advantages: Nuclear reactors are emissions-free. They emit no carbon dioxide, no air pollutants such as sulfur dioxide, oxides of nitrogen, and no particulates, all of which are linked to adverse health and environmental impacts.[49]

Second, nuclear energy provides an alternative to coal-fired power plants. Over the past three decades, coal's share of the global electricity sector has stayed at about 40 percent.[50] Coal continues to be popular because it is scalable, reliable, affordable, and it provides baseload power. But that popularity has resulted in increased carbon-dioxide emissions from the electric sector. Nuclear reactors provide an alternative to coal-fired power plants, particularly in developing countries.

Third, nuclear energy has very high power density, meaning it doesn't need much land. For example, the Indian Power Energy Center in Buchanan, New York, sits on about one square kilometer of land and can generate 2,069 megawatts of electricity. Thus, the power density of the nuclear plant is nearly 2,100 watts per square meter (W/m^2).[51] For comparison, the power density of wind energy is between 0.5 and 1.5 W/m^2.[52]

Fourth, nuclear plants help diversify the country's electric grid. Just as it is risky to invest all your money in a single stock, it's equally dangerous to rely too heavily on one source of energy. Over the past few years, the US has dramatically increased the production of gas-fired electricity and decreased its reliance on coal-fired generation. That transition toward natural gas has helped reduce emissions, but it has also made the electric grid more reliant on a single fuel. During extreme weather events, the gas grid can be overtaxed and unable to supply sufficient quantities of fuel to consumers.

Fifth, fuel diversity helps assure resilience. Nuclear plants require refueling every 18 to 24 months. That makes them less vulnerable to supply disruptions like those that can effect electricity producers who rely on natural gas, and therefore must get just-in-time delivery of their fuel by pipeline. During the extreme-cold events in 2014 and 2019, US nuclear plants maintained near-maximum uptime, a fact that displayed their importance to the resilience of the electric grid.

Finally, nuclear energy provides baseload energy. Unlike renewable sources, which must be backed up with other fuels, and in particular, natural gas-fired generators, nuclear units provide stable, always-on power. That always-on power

helps provide grid stability and assures that electricity is always available in large cities and industrial facilities.

The US has been a leader in nuclear technology since World War II. If the US is to continue being a leader in nuclear-energy innovation, commercialization, and deployment, the nuclear sector will need strong, bipartisan, sustained support from Congress and the White House. By sustained support, I mean decades-long support. That political support will be needed to keep existing reactors in operation and to support the development, deployment, and diffusion of the next generation of nuclear technology both here in the US and around the world. The recently introduced Nuclear Energy Leadership Act is a good step in that direction.[53]

But let me be clear: the nuclear sector faces myriad challenges.The biggest and most influential environmental groups in the US continue to oppose nuclear energy.[54] The existing fleet of reactors continue to be undercut by low-cost natural gas in the power sector. New nuclear reactors still cost way too much. Furthermore, Congress continues to dawdle when it comes to the issue of Yucca Mountain and long-term nuclear waste storage and disposal.

I don't expect a quick or easy resolution of this issue. But I must reiterate my point: there is no reasonable or affordable pathway to decarbonization of the global electricity business that does not include large-scale deployment of nuclear energy.

If the US wants to foster the innovation needed to sustain growth in nuclear-energy technology, Republicans and Democrats will have to forge significant, long-term commitments toward that goal.

Thank you.

END

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The CHAIRMAN. Thank you.

Lots, lots to begin with here this morning. I appreciate the contributions of each of you. And clearly, there is an agreement that technology is how we address these issues of increased emissions or worldwide, global emissions. But as you have pointed out very, very clearly, Ms. Ladislaw, you can have all the great technology but if we do not have the deployment out there, we have not even started to leave the house yet. So how we make that leap is part of our discussion here.

The other thing that I have underlined from your testimony that I really appreciate is this recognition that we need to be all in on all-of-the-above. When we determine here in Congress through our policies, or perhaps our policies by default, that we are going to favor one over another by way of subsidies or credits or what happens, as you point out, Mr. Bryce, with state policies that say we want to have renewables, except we do not want your kind of renewable, that is where we start to get in our own way here.

The question that I would pose to you all as a panel is, there is no shortage of good ideas with the technologies that are out there but we are stumbling in the deployment end of it. What should our role be here in the Congress to help facilitate to a better level this deployment? I am all in on what Senator Alexander has proposed in terms of increasing the funding for research and development and doubling up on ARPA-E, but outside of the obvious, what more do we need to be doing?

[The information referred to follows:]

One Republican's Response to Climate Change: *A New Manhattan Project for Clean Energy*

10 Grand Challenges for the Next Five Years

Advanced Nuclear
Natural Gas
Carbon Capture
Better Batteries
Greener Buildings
Electric Vehicles
Cheaper Solar
Fusion
Advanced Computing
Double Energy Research Funding

I believe climate change is real.

I believe that human emissions of greenhouse gases are a major cause of climate change.

And I believe the Democrat cure for climate change, their "Green New Deal," is so far out in left field that not many are going to take it seriously.

So, as one Republican, I propose this response to climate change: the United States should launch a New Manhattan Project for Clean Energy, a five year project with Ten Grand Challenges that will use American research and technology to put our country and the world firmly on a path toward cleaner, cheaper energy.

Meeting these Grand Challenges would create breakthroughs in advanced nuclear reactors, natural gas, carbon capture, better batteries, greener buildings, electric vehicles, cheaper solar and fusion. To provide the tools to create these breakthroughs, the federal government should double its funding for energy research and keep the United States number one in the world in advanced computing.

This strategy takes advantage of the United States' secret weapon: our extraordinary capacity for basic research, especially at our 17 national laboratories. It will strengthen our economy and raise our family incomes.

This strategy also recognizes that, when it comes to climate change, China, India and other developing countries are the problem; American innovation is the answer. According to the Global Carbon Project, over the last 13 years, the United States has reduced production of greenhouse gases more than any major country. But over the last five years, China's carbon emissions have risen. The U.S. reduction is largely thanks to conservation and switching from coal to natural gas to produce electricity.

A California physicist put it this way: Our mothers told us as children to clean our plates because children in India were starving. Cleaning our plates was a good thing to do, but it didn't do much for starving Indian children. In the same way, reducing carbon emissions in the United States may be good to do, but it doesn't do much to address climate change because most of the increase in greenhouse gases is in developing countries. If we want to do something about climate change, we should use American research and technology to provide the rest of the world with tools to create low cost energy that emits fewer greenhouse gases.

The purpose of the original Manhattan project during World War II was to find a way to split the atom and build a bomb before Germany could. The New York Times described this as the "most concentrated intellectual effort in history." Instead of ending a war, the goal of this New Manhattan Project will be to minimize the disruption on our lives and economies caused by climate change, to clean the air and to raise family incomes – both in our country and in the rest of the world by creating large amounts of clean, inexpensive energy.

Can a New Manhattan Project accomplish such bold breakthroughs in just five years? Well, just look at what has happened in the United States during the *last* five years: carbon emissions from energy consumption are down by 230 million metric tons; the number of electric vehicles has doubled and so has the median driving range per charge; the utility scale cost of solar power has been nearly cut in half; the number of homes has risen 4 percent, but household energy usage has decreased by 10 percent; we lost and then reclaimed the number one spot in supercomputing; the cost of natural gas has been cut in half, and the percent of electricity provided by natural gas has increased from 27-percent to 35-percent – all in the last five years.

I will not spend time in these remarks debunking the Green New Deal, because so many others so effectively have already done that. Basically the Green New Deal is an assault on cars, cows, and combustion. With nuclear power available, its strategy for fighting climate change with windmills makes as much sense as going to war in sailboats. As a bonus, it throws in free college, a guaranteed job with a government set wage, and would take away private health insurance on the job from 170 million American workers. No one has any earthly idea what it would cost taxpayers.

You don't have to believe humans cause climate change to believe in the New Manhattan Project for Clean Energy, and you don't have to be a Republican. Hopefully the New Manhattan Project for Clean Energy can become a bipartisan proposal. Many of its Ten Grand Challenges have also been proposed by the National Institute of Engineering and the National Academy of Sciences. At different times, Barack Obama and John McCain, Newt Gingrich and Howard Dean, all have called for a Manhattan Project for new energy sources.

These are the Ten Grand Challenges:

Advanced Nuclear — Ninety-eight nuclear reactors produce 60 percent of all carbon free electricity in the United States. There has never been a death as a result of an accident at one of these reactors. The problem is, in competition with natural gas and coal, these reactors cost too much to build and some cost too much to operate. According to the Energy Information Administration, eleven reactors may shut down during the next five years. Building the Vogtle nuclear plant in Georgia, the only two new reactors being built in the U.S., could cost as much as $27.5 billion. Building two natural gas plants to create the same amount of electricity would cost less than $2 billion. We need to stop talking about advanced reactors and actually build something. Within the next five years, we need to build one or more advanced reactors to demonstrate the capabilities they may bring—lower cost, increased safety, and less nuclear waste.

Natural Gas — During the 1980's, American enterprise and technology created a new, cheaper way to produce natural gas allowing the U.S. to lead the world in reducing carbon emissions, because natural gas has about half the carbon emission of a typical coal plant. Continuing to develop new combustion technologies will make natural gas fired electric generation more efficient and further reduce carbon emissions.

Carbon Capture — This is the holy grail of clean energy. Coal is cheap and there is a lot of it. Already we know how to capture sulphur, nitrogen, and mercury from coal plants to clean the air. If we can figure out a way also to capture carbon at a cheaper cost and find large scale uses for its byproduct – for example, CO2 to ethanol – coal could be used everywhere in the world. The Natural Resources Defense Council has argued that, after conservation, coal with carbon capture is the best option for clean energy.

Better Batteries — The all-electric Nissan Leaf that I bought in 2011 had a hard time getting me from the Capitol to Dulles airport and back. Its real range was about 70 miles. Today's Nissan Leaf can travel 226 miles on one charge. A Tesla Model S can travel 335 miles. The price of lithium-ion batteries should fall another 45 percent during the next five years. Better batteries also can one day allow utilities and their customers to store large amounts of electricity during non-peak hours.

Greener Buildings — Despite considerable recent progress, this is still the real low-hanging fruit. Residential and commercial buildings still consume 39 percent of U.S. energy.

Electric Vehicles — Ten years ago there were no mass produced electric cars on U.S. highways. Today, there are one million and automakers are making investments to make millions more.

Cheaper Solar — Solar power has grown by 1500 percent since 2011, but still accounts for only 2 percent of U.S. electricity. The new goal for the Department of Energy's Sunshot initiative is to lower the cost of solar another 50 percent to .03 per kilowatt hour for utility scale solar.

Fusion —This is the ultimate green energy dream: make electricity on earth the way the sun makes it. Instead of splitting elements, combine them and make clean, almost limitless energy without waste. This is still a dream, but there can be meaningful progress in five years.

Advanced Computing — China, Japan, the U.S., and the European Union all want to be first in advanced computing. The stakes are high because the winner has an advantage in such things as advanced manufacturing, simulating advanced reactors and weapons before they are built, finding terrorists and saving billions of Medicaid waste, and simulating the electric grid in a natural disaster. The US regained the number one spot last year

thanks to sustained funding by Congress during both the Obama and Trump Administrations.

Double Energy Research Funding— Advanced computing is the first tool the New Manhattan Project needs to meet its Grand Challenges. The second tool is money. It would take $6 billion annually to double funding for the Department of Energy's Office of Science and its 17 national laboratories, which are where most of the our nation's basic energy research is done. By comparison, many estimate the cost of the Green New Deal is trillions annually.

This is a bold agenda—and hopefully a bipartisan agenda—that can over the next five years place Americans firmly on a path toward dealing with climate change, and at the same time produce large amounts of reliable, clean energy that lifts family incomes in our country and around the world.

I would like to include in the record:

1) An op-ed in the New York Times, authored by Richard Muller, a professor of physics at the University of California, Berkeley: "The Conservsion of a Climate-Change Skeptic" and

2) An address I made in Oak Ridge in 2008 calling for a "New Manhattan Project for Clean Energy Independence."

The CHAIRMAN. You have indicated, Mr. Sandalow, that we need to be focusing on longer-term visioning so that investors then are interested in coming to the table. But help me out. Let's have this conversation.

Go ahead, anyone can jump in here.

Ms. LADISLAW. Well, I'll offer just a couple of ideas. I mean, I think, you know, there was a Wall Street Journal article that had most of the prominent economists saying that the carbon tax is probably the most efficient way of trying to send that signal to market.

I would say most of the people that I talked to in the energy field somewhat agree, right? I mean, I've had people tell me, CCS wouldn't actually be terribly hard if you had a high enough carbon price to at least, you know, be trying more of it in the field, right? And so, however those economists aren't in Congress, right? That's not, they don't exist here——

The CHAIRMAN. Well, that goes back to Mr. Sandalow's point about politics.

Ms. LADISLAW. Yeah, so I think that if you look at like policies like a clean energy standard, most states have renewable portfolio standards. A lot of them are revising them now. They know what they are. They know what they do.

You could have a federal level clean energy standard that tries to build on that, that says well, let's try and—you could probably do most of the work that you need in the electric power sector, in terms of decarbonizing through a policy like a clean energy standard.

So there are lots and lots of performance-based energy standards that you can put in place that say I don't care how you get there, but here's the target, here's the goal.

And we apply some of those standards in our innovation programs, right? I mean, be supporting those national standards. We just need them echoed out there in the market as well.

The CHAIRMAN. Mr. Sandalow?

Mr. SANDALOW. I completely agree with Ms. Ladislaw.

You know, these clean energy standards, or renewable portfolio standards, have been very successful at the state level. Applying that to the federal level would be a big step forward.

In some ways, even an easier step could be eliminating fossil fuel subsidies. I mean, why are we subsidizing fuels that are polluting the atmosphere? If we could get rid of those, that would provide a level playing field for some of these clean energy technologies.

And then I would point to the point I made about planning in my testimony. You know, it's striking to me some European governments, some Asian governments, they set 5-, 10-, 15-year targets on these long-term issues and then they adjust as they go forward. In this country, we celebrate it when we pass a one-year appropriations bill. I think we can to better. And we should work to have 5-, 10-, 15-year targets. The Department of Energy has tremendous expertise to help with that and really do long-term planning in a way that we don't today.

Mr. SILVERMAN. I was just going to add to that, you know, a green grid is largely an economics problem frankly, not a technical problem. We can get to, you know, 10, 20, 30, 40 percent, whatever

the standard that we need, whatever the climate change science tells us we need to do, we can get to that standard. The market can get there using economic principles and that really does mean choice and then going through and creating the kind of durable market structure that will actually attract private capital.

I know there's always a temptation to want to subsidize and to use tax dollars, but really we will be much better if we have a public-private partnership where we have a durable market structure that drives that kind of private investment. You really want to unleash that and bring it into the market.

And again, that comes back to having that nice, solid market. And unfortunately, you know, we've seen really a retreat from markets as if somehow markets and green outcomes are incompatible. And so, I would love to see this Committee, sort of, go at that, go at that issue head on.

The CHAIRMAN. Doctor?

Dr. MAJUMDAR. If I could just add.

Energy infrastructure lasts for 50, 60, 70 years. We have to think about this as the 21st century game, and we have to take the lead on this because the rest of the world also has to change.

Given that, coming back to the planning, the long-term planning, I completely agree with some of the things that Mr. Bryce was talking about and I outline that in my written testimony. This whole idea of looking at 1936 Rural Electrification Act, if he could create a similar kind of thing to get the clean energy services deployed into our cities and towns and villages, that will require the federal, state and local governments to come together and streamline the permitting and the regulatory process to expedite it.

We need to create, figure out, how to get private capital into the energy system. And there is, Senator Coons and others have put a Master Limited Partnerships Parity Act which will essentially put everything on a level playing field.

Talking about the price on carbon. Where markets work, they are efficient. We could either have a direct price on carbon or an indirect price whether it's a clean energy standard, it's an indirect price on carbon. But we need to have to accelerate that. Technology innovation is not enough. We need the market pull.

But there are places where the markets don't work. And we know. And there are market failures in energy efficiency. That's why we have appliance standards. That's why we have clean fuel efficiency standards.

And I would go full force in creating, not just building codes which are for design, but actual performance-based standards for the buildings across the United States. I think if you could do that and provide the infrastructure to deliver these solutions, I think that's the transition path that I see.

The CHAIRMAN. Very good.

Mr. Bryce, you are the only one that has not spoken. We are out of time, but go ahead.

Mr. BRYCE. Yes, ma'am.

My quick comment would be what is the priority? It would, I'm sorry I'm a one trick pony here. It's a sense of urgency on the deployment of nuclear energy at scale.

The United States is not the world. The coal sector, globally, in the global electric sector, coal's share of electricity generation has stayed at about 40 percent for 30 years. What can supplant coal in developing countries as baseload form of electricity generation? It would be nuclear, but the U.S. has to play in that game and right now that game is being dominated by the Russians, the Chinese, the Indians and the South Koreans.

And that is where the U.S., I think, could make a long-term, lasting contribution but it would have to be done with urgency and it would, it's going to require significant federal involvement.

The CHAIRMAN. Thus, the need for NELA.

[Laughter.]

Senator Manchin.

Senator MANCHIN. First of all, I think, and do you agree, that we need increased funding for the DOE as far as technology research and development? Everybody agrees on that, okay.

Mr. Silverman, on the Petra Nova company's carbon capture facility in Houston, I had a chance of visiting them. I really enjoyed this visit.

Petra Nova is the only U.S. power plant currently generating electricity and capturing carbon dioxide in large quantities, about 5,200 tons per day, and I understand over a million tons within the first ten months.

And so, I would ask, of all of you, you have the only commercialized experience in that realm. How does it work? What have you learned from it? Can it be done? And should it be continued?

Mr. SILVERMAN. Absolutely, it could be done because we're doing it. It's an incredibly exciting project, and we're all very proud of it.

I mean, CCS is one of the—carbon capture and sequestration is one of the potentially least cost methods of getting to fight climate change. You know, it is an experimental project. It is absolutely dependent on federal R&D dollars and, you know, it is a difficult and frankly, you know, any time you deploy a new technology, it always takes a while to get it right.

But you know, when we look forward to a market structure that really is an all-of-the-above, if we want carbon-free power, let's talk about including letting nuclear compete against renewables, compete against carbon capture and sequestration, compete against repowering or shutting other facilities down.

If we have that transparent price in that market mechanism, we really are looking at an all-of-the-above because we're talking about having a market structure that will allow us to come in and finance that kind of innovation, particularly as it gets more commercialized. I don't think we're there yet. But as it gets more commercialized, if we have that transparent market structure then all of these technologies will compete and we really will find the least cost solution out there.

Senator MANCHIN. What I am hearing from all of you is that, basically, there is a challenge with renewables, as far as where we should go and wherever we are going with it may have a road block. I think, Mr. Bryce, you have pointed out the road blocks that are out there.

Now I am for getting it up to the level of power sources that we are going to need in order for the country to have what it needs,

I understand that. What about China and India and Asia, where they are coming on so strong with coal, what are they going to rely on? That is my concern.

Global climate is not the U.S. climate, and it is not North American climate. And for some reason we lose sight of that. We think that if we can basically penalize, or whatever, the rest of the world is going to follow suit. I don't see, from what I understand, the average coal-fired plant in Asia is what, 11, 12 years of age? They plan on running them for another 30 years. What are you all planning to do there? How do we get them onboard?

Mr. SANDALOW. Thank you for raising the issue, Senator. It's absolutely fundamental to solving this problem.

You know, the United States is the largest cumulative emitter of carbon dioxide over the past 100 years.

Senator MANCHIN. Right.

Mr. SANDALOW. With the second largest in the world, but last year the vast majority of greenhouse gases came from outside the United States.

Senator MANCHIN. Absolutely.

Mr. SANDALOW. When you say there's no solution without engaging China and India, one core piece is U.S. leadership. One thing I hear all the time when I travel is, we think you're not doing anything on climate change right now because your political leadership is denying the reality of it. And I say, that's just not true. Look at the statistics, look at what we're actually doing. But that type of political outlook is extremely important.

Then, innovation in low-carbon technologies, I mean when we produce cheap solar innovations, when we produce innovations in a variety of other areas, they spread around the world. And that's going to be a core part of the solution.

Senator MANCHIN. Let me just interject, if I could——

Mr. SANDALOW. Please.

Senator MANCHIN. ——because our time is running short.

If that is the case and carbon tax, or carbon pricing, a carbon pricing to find the solution for carbon emission is one thing. Carbon pricing to basically restructure or redistribute the wealth and does not find the solution, does not make any sense to me at all. It just really does not make sense to me that you are saying we are going to put a carbon price on but we are not going to use to find the solution. There is no way that China or Asia is going to use this, because they are not going to do the same. That is going to be a self-inflicted wound.

Anybody want to jump in on that?

Ms. LADISLAW. I think there are ways of mitigating the impact of a carbon price, and it depends on the pricing mechanism, right? So, cap and dividend is a lot of what people are focusing on now because——

Senator MANCHIN. That is popular, give them a price. Okay, fix the problem.

Ms. LADISLAW. Well, to be honest with you, like, I think the appropriate way to think about China is that they're both a leader and a lagger in emissions, right? They emit a ton, but they're the largest market for low-carbon energy, right? They're making that market——

Senator MANCHIN. Unfortunately, they are still emitting more than we will ever emit. They are polluting more than has ever been polluted.

Ms. LADISLAW. And I think that that's true.

Senator MANCHIN. And you think they are going to put a carbon tax on?

Mr. SANDALOW. They have, Senator.

Ms. LADISLAW. They have.

Senator MANCHIN. They have?

Mr. SANDALOW. Yes.

Ms. LADISLAW. Well, they have cap and trade programs and their demonstration programs and largely, I think, that that's part of——

Senator MANCHIN. They won't even run their emissions at night. They are not even taking—I mean, their nighttime emissions, look at the emissions they have at night versus day.

Ms. LADISLAW. Right.

So, quick analogy. I'm from New England so I do hockey analogies, right? And I think part of the challenge on climate change and technology is to skate to where the puck is going. I think that they're investing a ton of money in markets that are about low-carbon technology with——

Senator MANCHIN. We are talking within a ten-year span, and the only way you are going to do it is decarbonizing the use of fossil fuels through technology and more nuclear. That is the only way I see to quickly get at a ten-year to where we can save the planet.

Ms. LADISLAW. Sure. Just get them into the market.

Senator MANCHIN. Go ahead.

Mr. SILVERMAN. Senator, one thing to keep in mind is the greatest threat to our existing coal facilities is subsidies because we cannot compete if a state has started handing out free money to our competitors. That will kill our coal facilities faster than anything else.

Senator MANCHIN. Do you mean subsidies to coal plants?

Mr. SILVERMAN. No, not to—subsidies to coal plants, frankly, don't work either, but for a different reason. But what I'm talking about are competitors getting subsidies whether it be renewable or nuclear subsidies.

Senator MANCHIN. I got you.

Mr. SILVERMAN. They do not work with the competitive market, and we rely on the competitive market.

So the reason a carbon tax actually is preferable from our point of view isn't that it's good for coal plants, because it's not, but what it does is it has a market mechanism that we can then compete against. And it preserves the integrity of the existing competitive markets and that actually allows us to deploy capital in a much more sensible way because, you know, if we are faced with our competitors, other technologies, operating basically for free, then there is no more competitive market. Ratepayers and consumers have lost the benefits. And you know, I would much rather have a tough competitive market that I can actually compete in than a market that I can't compete at all.

Senator MANCHIN. Thank you, Madam Chairman.

The CHAIRMAN. Thank you, Senator.

Senator Alexander.

Senator ALEXANDER. Thank you, Madam Chairman.

Thanks to the panel.

Ms. Ladislaw, I heard a California physicist who switched from being a climate skeptic to a climate believer say this. He said, "When we were little our mothers told us to clean our plates because the children in India were starving." That was a good thing to do, but it did not help the starving children in India. He said, "Climate is a lot the same. We can do everything here, but the problem is there."

If you look at the statistics, we have reduced carbon emissions more than any other country in the last 15 years. China has tripled. India has doubled. So if we are looking at the near-term, why wouldn't we try to help the rest of the world do in the near-term what we have done in the last 15 years?

It seems to me what we have done in the last 15 years is maintain our nuclear reactors, that is 60 percent of our carbon-free emissions, and introduced natural gas and conservation in smokestacks and tailpipes. It looks to me like natural gas and conservation has been the reason for our reduction. What can we do in the next near-term to help the rest of the world do that?

Ms. LADISLAW. There's a lot that we can do. I think selling other countries our technology, exporting some of the energy that we produce here is a good example.

I think your focus on if we want nuclear to be part of the solution, the United States is going to have to work much, much harder to bring some of those advanced nuclear technologies out into the field. It's not competitive now, and we're not competitive internationally to do that. So I think there are a lot of those, sort of, very smart things that the U.S. can do to promulgate and, quite frankly, has done that around the world.

We run a project where we connect U.S. states and Indian states to try and——

Senator ALEXANDER. Well, why don't they use natural gas and conservation in India and China?

Ms. LADISLAW. Well, they're trying. I mean——

Senator ALEXANDER. Well, if it worked for us why wouldn't it work for them?

Ms. LADISLAW. Well, I mean, to be honest with you we've had the largest surge in natural gas production over a ten-year period of five.

Senator ALEXANDER. Oh, I know, well why don't they?

Ms. LADISLAW. Well, they would love to if they could.

Senator ALEXANDER. Why can't they?

Ms. LADISLAW. Well, we have a giant industrial base of natural gas companies and a huge resource here.

Senator ALEXANDER. If you can make money there, can you not make money in India?

Ms. LADISLAW. Yes, the resource base isn't there in India for unconventional gas.

Senator ALEXANDER. But I am saying it looks like the problem is there in the solution.

Mr. Bryce, let me move to nuclear with you. Nuclear is 60 percent of our carbon-free emissions. The estimates are that 15 to 20

of our reactors, of our 100 reactors, will close in the next ten years. Let's say 30 close. That eliminates, by my math, 18 percent of our carbon-free emissions. That is the total amount of carbon-free emissions that wind produces in the United States after 25 years of billion dollars of subsidy.

So a great many people who are urgently concerned about climate change are switching their view to say it is really wrong not to emphasize nuclear.

So you and I believe that. Exactly what should we do in the next near-term, in addition to the advanced reactors which are down the road, for results? What should we do to keep 15 to 20 reactors from closing in the next ten years and to producing more nuclear power in our own country?

Mr. BRYCE. It's a very difficult problem, Senator, and Mr. Silverman and his company is facing this.

I think, to me, one of the simplest ways to address it is do a contract for difference. If these nuclear plants can show that they're operating at a loss, subsidize them to the point where they can compete and/or get made whole in the wholesale market.

But the U.S. electricity market is extraordinarily fragmented. There are a lot of players and there is going to be a lot of opposition to that kind of, call it what it is, a subsidy.

But I agree with you that if those plants close, they're going to be replaced by natural gas-fired power plants. I'm pro-gas but that means an increase in CO_2 emissions.

Senator ALEXANDER. Right.

Let me use my last question for Dr. Majumdar.

As you know I have always thought that carbon capture is the holy grail of what we are talking about because if we ever could commercially capture it at a cost that mattered and find something to do with the result of what we had captured, why, we could burn coal everywhere in the world and since we know how to deal with sulfur, nitrogen and mercury and that would be carbon.

You worked on that some at ARPA-E. What did you find? Is that ever going to happen? I don't mean sequestration. I mean some other physical, biological invention that I am not smart enough to know about. Is that ever going to happen?

Dr. MAJUMDAR. Well, Senator Alexander, I think one of the last reports we wrote as part of Secretary Moniz's Advisory Board was on exactly this issue—how do you do global carbon management and carbon capture is absolutely the right in it.

Today if you'd look at a coal-fired power plant and tried to capture the carbon, it costs about $60 a ton. That needs to come down to about $30, $20–$30 a ton because there is a market on carbon for enhanced oil recovery et cetera, which is about roughly $30. So, if the cost is lower than the price in this business and so, that needs research, that needs new technologies to be created.

And so, I think this is absolutely the right thing to do and, in fact, in talking with India since I go there once a year, and every time I go there to New Delhi, to meet and talk to the government and the businesses. They're looking for technology. They realize that they have to shift. They're looking at their air pollution, and they realize that they cannot survive this way.

And so, they're looking for technology and I think if you look at China and India broadly at an international level, they look at this 21st century shift and they want to be part of the supply chain which is going to be a new supply chain. And I think we need to think strategically to see how we can capture a large value of the supply chain in the United States and part of that is technology innovation.

Senator ALEXANDER. Thank you, Madam Chairman.

The CHAIRMAN. Thank you, Senator Alexander.

Senator Stabenow.

Senator STABENOW. Well, thank you, Madam Chair and Ranking Member, for holding another very important and thoughtful hearing. I really appreciate this, and I appreciate the fact that we are focusing on the opportunities of addressing climate change as well as the serious impacts on carbon pollution. I appreciate we are actually talking about climate change as a real thing and that we need to actually do something about it which is a wonderful conversation at least to have.

Given the volatility of the weather, which is getting worse all the time because of carbon pollution, and what we are seeing in the atmosphere in the warming of the atmosphere and holding more snow, holding more rain, I mean all of this is happening. Coming from a state with a large agricultural presence I know it is dramatically changing what is happening for us and not in a good way.

I also just want to raise for us, to me, even though this obviously is a global issue, it starts with American leadership which means we should be in the Paris Climate Accord and as a voluntary leader. But it also means that we are impacted right now.

We have a disaster assistance bill on the Floor, another one, billions of dollars. Taxpayers in America are paying. It is a question of are we going to pay for innovation and jobs or are we going to pay for picking up the pieces because of all of the volatility in the weather and what has been happening.

So it is not a surprise that I, coming from Michigan, am focused on ways in the transportation sector to be able to address this, as well as other areas. And we know from the United States' perspective this is the largest source of emissions.

And so, yesterday I was very pleased with Senator Alexander's and our peers and Senator Collins to introduce the Driving America Forward Act to extend the tax credit for the purchase of electric and fuel cell vehicles. We need to do that until there is a broad enough adoption that we can actually see the price come down, which it eventually will, but we do know that this creates jobs. It is creating jobs in my home State of Michigan and is a very important part of the all-of-the-above structure.

Let me just say that electric vehicles can reduce carbon pollution by up to 70 percent and as the power sector becomes more increasingly green, life cycle emissions will drop further. This is a good thing.

Also, hydrogen fuel cells, I don't think we have focused enough in that area. I know that we have global competitors in China and Japan that are investing heavily and have even shorter refueling times and longer driving ranges for electric vehicles.

I do want to say on the hydrogen fuel cell, and because this is part of our legislation, when I talk hydrogen fuel cells people often think of the Hindenburg and we are not talking about dangerous fuel here. In fact, in many ways, it is safer than gasoline. The army now, in Michigan, tactical, our U.S. Army research arm is working with the Department of Energy on developing fuel cell tactical vehicles, and that is very exciting to see what they are doing.

So when we look at this, but my concern—let me just ask Mr. Sandalow, when we look at how we bring down the cost in terms of deployment and so on, we know that the battery accounts for about 30 percent or more of the cost right now in an electric vehicle. And in fact, McKinsey is reporting today that about the importance of lowering battery cost. I am wondering for yourself and Mr. Majumdar, how can Congress, the Federal Government, speed up the commercialization of this? I mean, we are hearing that it could be 20 years before we see the research necessary on battery technology. That is just not fast enough.

Mr. SANDALOW. Senator, thank you for the question.

I think the bill you submitted yesterday is a great start on this. I think one of the lessons from our experience with the reduction of costs of solar power is that scale makes a big difference. Once these technologies are deployed in large volume, the costs come down.

Senator STABENOW. Right.

Mr. SANDALOW. And the same thing is going to be true with electric vehicle batteries. I've seen projections that are more optimistic than the one you just related.

Senator STABENOW. Good.

Mr. SANDALOW. Projections that say that the purchase price of electric vehicles is going to be competitive with the purchase price of comparable conventional vehicles in the middle part of the next decade.

Already electric vehicles are probably cost competitive on a total cost of ownership basis over the life of a vehicle because it's cheaper to drive on electricity than on fuel. But people don't buy cars that way. They look at the sticker price. And so, once we get that purchase price comparable, it's going to make a big difference. And so, I think deployment policies are what's absolutely central here.

Senator STABENOW. Well, let me just add that infrastructure is also absolutely critical because right now people want to know how are they going to be able to charge their vehicle. If they can do that at work and they can feel comfortable at home, I think we will see much more rapid deployment.

I know I am out of time but Mr. Majumdar, I am not sure, I am so sorry if I am pronouncing that incorrectly. If you just had a sentence or two you wanted to add to that in terms of what we should be doing?

Dr. MAJUMDAR. I think with any new technology, as we do more, the cost comes down. That's the learning curve. And sometimes initially it is a little too high, maybe just maybe a little higher and cannot compete. So, they need a first market.

I come from Silicon Valley and people think Silicon Valley was created by venture capitalists. It's wrong. It was created by the Dean of Engineering of Stanford, Fred Thurman, who used to work

in the Department of Defense during the World War. When he went back to Stanford, he asked the Department of Defense to create the market for the Hewletts and the Packards, et cetera.

So the government has a role to play to create the first market. We are the biggest, the government is the biggest user for energy in the United States. And I think if you could use that power, the market demand power to bring down, to increase the scale and bring down the cost in the United States, you will then see the supply chain of manufacturing, et cetera, to be established out here. And I think that's one that should be on the table as we speak about this.

Senator STABENOW. Thank you.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator.

Senator Cassidy.

Senator CASSIDY. You know I am a physician so I look at things empirically. I have to admit that some of what has been said does not seem, and I mean this by no offense, some of what has been said does not seem to empirically hold up.

I mention that because this is such an important issue and it can't be, kind of, don't we wish this would be reality. It has to be the reality.

I will point out that if you look at that portion of our usage which is the industrial base of the grid, that is mobile. If you increase the cost of their input, they move and they move their jobs overseas. Indeed, since 1994 when the EU cap and trade and the U.S. regulatory system began on carbon, industry moved to China. And the increase in emissions by China exceeds the decreases in the EU and the U.S. put together.

Carbon leakage. And you can see what happened in Great Britain. They have achieved their success principally by the employment of natural gas versus coal and by carbon leakage. Now carbon leakage means you are moving to China which has coal at 63 percent of its fuel base despite voluntary, voluntary, voluntary regional cap and trade systems to China which continues to build, I think they are building coal-fired plants, not only in their own country but in 17 other countries simultaneously. They show no true commitment to this.

And a carbon tax? We would have to have a border adjustment carbon tax aside from WTO problems, empirically this is going to be complicated because of international supply chains.

Let me just say that is a preamble because this is too important to, kind of, hope. It has to be something embedded in empiricism, and empirically, frankly, Mr. Bryce, you seem to have it most.

No offense, sir, but if we look back and said 15 years ago, we are going to have a national, not market driven, but a national kind of priority, natural gas was $13 per MCF 15 years ago. Natural gas would not have been part of your fuel base because at that time industry was moving their fertilizer plants to Chile because they could not afford $13 per MCF. Now it is $2.50 and that same natural gas plant is moving back. So I think empirically, I think market forces are going to be that which is most.

And the renewables, it depends on how you define renewable. I understand renewable can be nuclear because it is always there. It

can be natural gas because, gosh, it always comes out of the ground. It could be wind and solar. But I think I know the physics limit the solar and wind from achieving anything beyond a marginal improvement in generation.

Mr. Bryce, any kind of comment on that?

Mr. BRYCE. Well, just a couple ones which is that when you're talking about, I have solar panels on the roof of my house. I have eight kilowatts of solar on the roof of my house. Solar is growing and growing rapidly. I'm bullish on solar. But it still has major land requirements.

Wind energy, they're reaching the limit. It's known as the Betz limit in physics which limits the amount of energy they can harness from the wind. So the only way to dramatically increase energy production from wind energy is by increasing the footprint of the wind turbines.

And as I testified, this backlash against the wind energy's encroachment is happening coast to coast and it's happening in my home State of Oklahoma. I talked to the Mayor of Hinton, Oklahoma, three days ago. They got sued by Next Air Energy because they passed an ordinance that prohibited the construction of wind turbines within two miles of their town's borders.

Senator CASSIDY. So, let——

Mr. BRYCE. They beat Next Air but I agree with you, sir, in terms of the growth of natural gas it's really a truly American success story.

Just to give you a couple of quick metrics. Just the growth in gas production in the U.S. from 2005 to today is roughly 44 billion cubic feet per day. That's two times Iran's gas output. It's four times Saudi Arabia's output.

Senator CASSIDY. So the degree to which the U.S. exports natural gas and coal use, India and China use our natural gas versus their coal, is the degree to which we will achieve significant decreases in global greenhouse gas emissions.

By the way, let me also point out that if you look at the academic journals, all of China's coal-fired plants on the Pacific Coast emit SO_X and NO_X that blows over the Pacific and lands on our Pacific Coast. The idea that we are going to somehow increase the price of energy on the grid and industry will not move to China and we won't have SO_X and NO_X blowing over on our country, I think, empirically is wrong. So I do think natural gas is the way to go.

Let me also say, I have never done this before, Madam Chair. I would like to submit a YouTube video for the record.

[Laughter.]

The CHAIRMAN. Are we capable of receiving that?

Senator CASSIDY. I don't know that.

[Laughter.]

[YouTube video transcript from Michael Shellenberger follows.]

Why renewables can’t save the planet | Michael Shellenberger | TEDxDanubia

Thank you very much when I was a boy my parents would sometimes take me camping in California. We would camp in the beaches in the forests in the deserts. Some people think the deserts are empty of life but my parents taught me to see the wildlife all around us the Hawks the Eagles the tortoises. One time when we were setting up camp we found a baby scorpion with its stinger out and I remember thinking how cool it was that something could be both so cute and also so dangerous. After college I moved to California and I started working on a number of environmental campaigns I got involved in helping to save the state's last ancient redwood forests and blocking a proposed radioactive waste repository set for the desert. Shortly after I turned 30 I decided I wanted to dedicate a significant amount of my life to solving climate change. I was worried that global warming would end up destroying many of the natural environments that people had worked so hard to protect. I thought the technical solutions were pretty straightforward. Solar panels on every roof, electric car in the driveway that the main obstacles were political and so I helped to organize a coalition of the country's biggest labor unions and biggest environmental groups. Our proposal was for a 300 billion dollar investment in renewables and the idea was not only would we prevent climate change but we would also create millions of new jobs in a very fast-growing high-tech sector. Our efforts really paid off in 2007 when then presidential candidate Barack Obama embraced our vision and between 2009 and 2015 the u.s. invested a hundred and fifty billion dollars in renewables and other kinds of clean tech but right away we started to encounter some problems. So first of all the electricity from solar rooftops ends up costing about twice as much as the electricity from solar farms and both solar farms and wind farms require covering a pretty significant amount of land with solar panels and wind turbines and also building very big transit lines to bring all that electricity from the countryside into the city. Both of those things were often very strongly resisted by local communities as well as by conservation biologists who were concerned about the impacts on wild bird species and other animals. Now there was a lot of other people working on technical solutions at the time. One of the big challenges of course is just the intermittency of solar and wind. They only generate electricity about 10 to 30 percent of the time during most of the year but some of the solutions that were being proposed were to convert hydroelectric dams into gigantic batteries. The idea was that when the Sun was shining and the wind was blowing you would pump the water uphill store it for later and then when you needed electricity run it over the turbines. In terms of Wildlife some of these problems just didn't seem like a significant concern so when I learned that house cats kill billions of birds every year it put into perspective the hundreds of thousands of birds rather that are killed by wind turbines. It basically seemed to me at the time that most if not all of the problems of scaling up solar and wind could be solved through more technological innovation but as the years went by these problems persisted and in many cases grew worse. So California is a state that's really committed to renewable energy but we still haven't converted many of our hydroelectric dams into big batteries. Some of the problems are just Geographic. It's just you have to have a very particular kind of formation to be able to do that and even in those cases it's quite expensive to make those conversions. Other challenges are just that there's other uses for water like irrigation and maybe this is the most significant problem is just that in California the water in our rivers and reservoirs is growing increasingly scarce and unreliable due to climate change. In terms of this issue of reliability as a

consequence of it we've actually had to stop the electricity coming from the solar farms into the cities because there's just been too much of it at times or we've been starting to pay our neighboring states like Arizona to take that solar electricity. The alternative is to suffer from blowouts of the grid and it turns out that when it comes to birds and cats, cats don't kill Eagles. Eagles kill cats. What cats kill are the small common sparrows and Jay's and Robins, birds that are not endangered and not at risk of going extinct. What do kill Eagles and other big birds like this kite as well as owls and condors and other threatened and endangered species are wind turbines. In fact they're one of the most significant threats to those big bird species that we have. We just haven't been introducing the airspace with many other objects like we have wind turbines. Over the last several years and in terms of solar you know building a solar farm is a lot like building any other kind of farm, you have to clear the whole area of Wildlife. So this is a picture of one third of one of the biggest solar farms in California called Ivanpah. In order to build this they had to clear the whole area of desert tortoises. Literally pulling desert tortoises and their babies out of burrows putting them on the back of pickup trucks and transporting them to captivity where many of them ended up dying and currently the current estimates are that about 6,000 birds are killed every year actually catching on fire above the solar farm and plunging to their deaths. Over time it gradually struck me that there was really no amount of technological innovation that was gonna make the sunshine more regularly or wind blow more reliably. In fact nothing you do could make solar panels cheaper. You could make wind turbines bigger but sunlight and wind are just really dilute fuels and in order to produce significant amounts of electricity you just have to cover a very large land mass with them. In other words all of the major problems with renewables aren't technical, they're natural. Well dealing with all of this unreliability and the big environmental impacts obviously comes at a pretty high economic cost. You know we've been hearing a lot about how solar panels and wind turbines have come down in cost in recent years but that cost has been significantly outweighed by just the challenges of integrating all of that unreliable power onto the grid. Just take for instance what's happening or Nia at the period in which solar panels have come down in price very significantly same with wind. We've seen our electricity prices go up five times more than the rest of the country and it's not unique to us. You can see the same phenomenon happened in Germany which is really the world's leader in solar wind and other renewable technologies. Their prices increased 50 percent during their big renewable energy push. Now you might think well dealing with climate change is just going to require that we all pay more for energy that's what I used to think but consider the case of France. France actually gets twice as much of its electricity from clean zero emission sources than does Germany and yet France pays half as much almost half as much for its electricity. How can that be? Well you might have already anticipated the answer. France gets most of its electricity from nuclear power. About 75% in total and nuclear just ends up being a lot more reliable generating power 24 hours a day seven days a week. For about 90% of the year we see this phenomenon show up at a global level. So for example there's been a natural experiment over the last 40 years even more than that or in terms of the deployment of nuclear and the deployment of solar. You can see that at a little bit higher cost we got about half as much electricity from solar and wind than we did from nuclear. Well what does all this mean for going forward? I think one of the most significant findings to date is this one had Germany spent five hundred eighty billion dollars on nuclear instead of renewables. It would already be getting a hundred percent of its end of its electricity from clean energy sources and all of its transportation energy. Now I think you might be wondering and it's quite reasonable to ask is nuclear power safe and what do you do with the waste? Well those are very reasonable

questions. Turns out that there's been scientific studies on this going over 40 years this is just the most recent study that was done by the prestigious British Medical Journal. Lancet finds that nuclear power is the safest it's easy to understand. Why according to the World Health Organization about 7 million people die annually from air pollution and nuclear plants don't emit that as a result the climate scientist James Hansen looked at and he calculated that nuclear power has already saved almost two million lives to date. It turns out that even wind energy is more deadly than nuclear. This is a photograph taken of two maintenance workers in the Netherlands shortly before one of them fell to his death to avoid the fire and the other one was engulfed in flames. Now what about environmental impact? WelI think a really easy way to think about it is that uranium fuel which is what we use to power nuclear plants is just really energy dense about his mouth about the same amount of uranium as this is this Rubik's Cube can power all of the energy that you need in your entire life. As a consequence you just don't need that much land in order to produce a significant amount of electricity. Here you can compare the solar farm I just described Ivanpah to California's last nuclear plant Diablo Canyon. It takes 450 times more land to generate the same amount of electricity as it does from nuclear you would need 17 more solar farms like Ivanpah in order to generate the same output as Diablo Canyon and of course it would then be unreliable. Well what about the mining and the waste and the material throughput well this has been studied pretty closely as well and it just turns out that solar panels require 17 times more materials than nuclear plants do in the form of cement glass concrete steel and that includes all the fuel used for those nuclear plants. The consequence is that what comes out at the end since its material throughput is just not a lot of waste from nuclear. All of the waste from the Swiss nuclear program fits into this room. Nuclear waste is actually the only waste from electricity production that's safely contained and internalized. Every other way of making electricity emits that waste into the natural environment either as pollution or as material waste. We tend to think of solar panels as clean but the truth is is that there is no plan to deal with solar panels at the end of their 20 or 25 year life. A lot of experts are actually very concerned that solar panels are just going to be shipped to poor countries in Africa or Asia with the rest of our electronic way stream to be disassembled often exposing people to really high levels of toxic of toxic elements including lead cadmium and chromium elements that because their elements their toxicity never declines over time. I think we have an intuitive sense that nuclear is a really powerful strong energy source and that sunlight is really dilute and diffuse and weak which is why you have to spread solar collectors or wind collectors over such a large amount of land. Maybe that's why nobody was surprised when in the recent science-fiction remake of Blade Runner the film opens a very dark dystopian scene where California's deserts have been entirely paved with solar farms all of which I think raises a really uncomfortable question in the effort to try to save the climate are we destroying the environment? Well the interesting thing is that over the last several hundred years human beings have actually been trying to move away from what you would consider matter dense fuels towards energy dense ones that means really from wood and dung towards coal oil natural gas uranium. This is a phenomenon that's been going on for a long time. Poor countries around the world are in the process still of moving away from wood and dung as their primary energies and for the most part this is a positive thing as you stop using wood as your major source of fuel it allows the forests to grow back and the wildlife to return as you stop burning wood in your home you don't you no longer need to breathe that toxic smoke and as you go from coal to natural gas and uranium is your main sources of energy it holds out the possibility of basically eliminating air pollution altogether. There's just this problem with nuclear well it's been pretty popular to move from dirtier to cleaner energy sources from energy

diffuse to energy dense sources. Nuclear is just really unpopular for a bunch of historical reasons and as a consequence in the past I and I think a lot of others have sort of said well in order to deal with climate change we're just going to need all the different kinds of clean energy that we have the problem is is that just turns out not to be true. You remember I discussed France a little bit ago. France gets most of its electricity from nuclear. If France were to try to significantly scale up solar and wind it would also have to significantly reduce how much electricity it gets from nuclear. That's because in order to handle the huge variability of solar and wind on the grid they would need to burn more natural gas. Think of it this way it's just really hard to ramp up and down a nuclear plant whereas I think we're all pretty familiar with turning the natural gas up and down on our stove a similar process works in managing the grid of course goes without saying that oil and gas companies understand this pretty well which is why we've seen them invest millions of dollars in recent years in promoting solar and wind this just raises I think another challenging question which is that in places that are using a lot of nuclear have grids that are mostly nuclear and hydro going towards solar and wind and other renewables would actually increase carbon emissions. I think a better alternative is just to tell the truth and that's what a number of scientists have been doing. I mentioned earlier that hundreds of thousands of birds are killed every year by wind turbines but what I didn't mention is that a million bats at a minimum are killed every year by wind. The consequence has been that bad scientists have been speaking out about this this particular bat species the hoary bat which is a migratory bat species is literally at risk of going extinct right now because of the significant expansion of wind it's not just wind it's also on solar. The scientists who were involved in creating the Ivanpah solar farm who involved in clearing that land have been speaking out. One of them wrote everybody knows that translocation of desert tortoises doesn't work when you're walking in front of a bulldozer or crying and moving animals and cacti out of the way. It's hard to think that the project is a good idea and now we can see these phenomena at work at an international level in my home state of California. We've been stuffing a lot of natural gas into the side of a mountain in order to handle all that intermittent solar and wind. It's sprung a leak it was equivalent to putting 500,000 cars on the road and currently in Germany there's protesters trying to block a new coal mining project that would involve destroying the ancient Han back forest in order to get to the coal underneath all in an effort to phase out nuclear and expand solar and wind. The good news is is that I think that people still care about nature enough for these facts to matter. We saw last year in South Korea a citizen's jury deliberated for several months weighing these different issues. They had to decide whether they were going to phase out nuclear or keep it and expanded. They started out 40 percent in favor of expanding nuclear but after several months and considering these issues they ended up voting 60 percent to expand nuclear. A similar phenomena just happened last week in Arizona. The voters had a ballot initiative that to vote on whether or not to continue with nuclear or to phase it out and try to replace it with natural gas and solar. They ended up rejecting at 70 to 30 and even here in Europe we saw the Netherlands is that one of the first countries in recent memory to actually announce as they did last week that they're going to start to they're gonna start to increase their reliance on nuclear power in recognition that there's just no way they could generate significant amounts of energy enough from solar and wind to meet their climate targets. I think it's natural that those of us that became very concerned about climate change such a big environmental issue would gravitate towards really romantic solutions like harmonizing human civilization with the natural world using renewable energies but I think it's also understandable that as the facts have come in that many of us have started to question our prior

beliefs and change our minds. For me the question now is now that we know that renewables can't save the planet are we going to keep letting them destroy it? Thank you very much.

https://www.youtube.com/watch?v=N-yALPEpV4w

Senator CASSIDY. It is by Michael Shellenberger who was formerly involved with the Obama Administration, who now goes on and says, listen if we are going to achieve a carbon-free future it cannot be solar and wind because the footprint required is requiring destruction of Joshua Tree, pulling turtles out of the ground, all of whom die, and cutting the forest and that that footprint cannot be expanded much further. Therefore, he, if you will, working with the Obama Administration, has said that we cannot go in that direction if we wish to achieve our goals. That said, thank you all for your testimony and I appreciate it.

The CHAIRMAN. Thank you, Senator. We will figure out how we put that video into the record. But thank you for that.

Let's go to Senator Hirono.

Senator HIRONO. Thank you, Madam Chair.

Mr. Majumdar, sorry, we seem to be doing damage to your name, I apologize.

I was particularly taken by the portion of your testimony that really points to a sense of urgency that we should have and particularly when you note that climate change is resulting in extreme weather conditions such as extreme heat and cold, droughts, excessive rainfall and we certainly saw that on the island of Kauai where more rainfall fell on that island in a 24 hour period than in the entire history of our country. That is saying a lot. The President had to declare a national disaster declaration. So, flooding, all of that.

And that a rise of the temperature, average temperature to two degrees Centigrade, and we are at 1.2 degrees Centigrade right now, would be devastating to the world and, by your calculation, it would just take us another 20 years to get to the point of a two-degree Centigrade temperature. And then thereafter, the emissions must be zero. So I think that the sense of urgency is there.

You noted in your testimony also that research alone is not sufficient to bring innovative technologies from the laboratory to a commercial scale where they can benefit people. Do you think the Department of Energy should support demonstrations, demonstrations of new technologies to improve the performance of the electric power grid to handle large amounts of renewable power, energy storage, electric vehicles and other needs?

Dr. MAJUMDAR. Senator, that's a great question.

I think that, so Department of Energy, in terms of ARPA-E, the applied energy program, energy and sciences, they're supporting research.

When it comes to demonstration, I think we should look at the needs of our states. We should look at the energy requirements and the diversity of what's required, because there's no one solution to climate change, as we all know. We have a diversity of solutions and there's a diversity of needs.

I think we should use the states' needs and create federal-state partnerships with the private sector to create the environment for demonstration projects so that they actually prove out and de-risk the technologies so that then the markets can look at that and say that that's what we want, not just U.S. markets but international ones. So I think we should use a leverage of states to demonstrate, to create demonstration projects.

Senator HIRONO. I think that is a very good point and, in fact, there are a number of bills that would support public-private partnerships to demonstrate, for example, innovative grid technologies so the grid can accommodate more renewables. We are always told by the utilities that their grids cannot accommodate more renewables, so that is really an area that I think we should focus on and I have a bill to do just that, strangely enough. But I do thank the Chair for including such demonstration grants in her Energy and Natural Resources Act last Congress.

Mr. Silverman, you spoke about using a carbon tax and Ms. Ladislaw, you spoke about a national clean energy standard to provide a way to recognize that we shouldn't allow fossil fuel plants to continue emitting carbon pollution for free. What are your views on applying a cap and trade system to set a limit on carbon pollution?

Mr. SILVERMAN. So we are very much in favor of an economy-wide carbon price, because it's very difficult to have competition across sectors if you don't have some common language. So, we do think that makes a lot of sense.

In terms of in the electricity sector, you know, we really do think the low-hanging fruit is choice. Let people buy it if they want. Senator Heinrich left, but businesses are actually some of our biggest customers demanding green power.

Senator KING. Heinrich is right here.

Mr. SILVERMAN. I'm sorry, Mr.——

Senator HIRONO. Cassidy.

Mr. SILVERMAN. Apologies. Thank you.

So, anyway, businesses are some of our best customers who want green power and, you know, not everywhere in the country can they buy it and that's very frustrating.

Now in terms of cap and trade we could, you know, this panel could go on forever talking about the various benefits of putting a price on carbon, absolutely. We tend to think that you actually have to make a policy choice between the lowest carbon grid tomorrow in which case a price on carbon is very, very effective or are you really interested in driving investment directly to zero carbon resources? Those are two different policy outcomes.

If you want the lowest carbon grid tomorrow, absolutely put a price on carbon. But if your goal is to drive investment in clean tech, actually it's a more direct subsidy or more direct means of getting it if you establish a market that values the clean energy attribute and then says, okay, we're open for business. Any technology that wants to come in can compete, because, of course, the climate doesn't care where we're getting our clean megawatts from. And so, we really do like having that direct price signal where the money goes directly to support clean energy investment as opposed to a carbon tax but we're very much in favor of sort of using both tools in conjunction where the use case makes sense.

Senator HIRONO. Madam Chair, could I ask Ms. Ladislaw to also give us her comments?

Ms. LADISLAW. Sure. I think a carbon tax, cap and trade system clean energy standard, there's public policy ways of designing each of these programs to meet a variety of different needs. So I have no problem with the cap and trade program.

I think there's a little, there's more in just today in, sort of, a tax and dividend scheme because it speaks to paying people back, right? And there's a concern that the tax, the increased cost for energy might harm people. And so, it really just is about priorities. And we've seen different states have cap and trade programs and they work well.

I think that the issue is we really need to kind of pick one and do it in earnest because a lot of time has been wasted sort of debating about the mechanisms and we, kind of, just need to do something.

Senator HIRONO. Thank you.

The CHAIRMAN. Senator Heinrich.

Senator HEINRICH. I am going to stay on the same thing and just first start, I am curious how many of you agree that putting a price on carbon pollution either indirectly or directly is a good thing? Anybody no? Okay. That is not bad. That is not 100 percent, but 80 percent is pretty good.

When it comes to if we put a price on carbon and in particular, Mr. Silverman and then also Ms. Ladislaw, that next step of how to use that price because one step is introducing the price on carbon. The next step is, is it a tax? If it is a tax then you use that to fund government. If it is a dividend or a fee, it goes someplace else next, either back to a consumer, for example, where you target it to the most exposed energy consumers to make sure that they don't bear the price of us cleaning up our grid or it goes someplace like into research or into the transitioning the workforce.

So do you have strong opinions on what that next step should look like?

Mr. SILVERMAN. Yeah, well, I have a 15-page version attached to my testimony. I'd be happy to talk about it more.

Where you sort of start getting really wonky, it's about setting up a market structure that delivers what we need at the least possible cost. Our wholesale markets, overseen by FERC, are just viciously competitive.

Senator HEINRICH. Absolutely. I hear where you are going with that, but so what we are doing up here is we are trying to marry what the economists all agree on with what the world of the political possible is and also trying to avoid, you know, what Macron just went through in France where the wrong people bore the cost of that transition.

Mr. SILVERMAN. Yeah.

No, and my only point about the competitive markets is the FERC angle has been completely ignored.

Senator HEINRICH. Absolutely, yes.

Mr. SILVERMAN. We have basically sidelined the people who are the best market designers in the world.

Senator HEINRICH. And that brings me to transmission which I disagree with this footprint issue. I mean, we have a lot of footprint to offer in New Mexico, and we are happy to sell clean power all day long to hungry markets.

We have one wind project that is about to break ground that is over half a megawatt or half a gigawatt, excuse me, not to mention all of the other projects in the pipeline right now.

But maybe one of the biggest challenges here is that there are very long lead times for actually creating the transmission to be able to marry those projects with where the demand is. Do you have strong opinions on what we ought to be doing on transmission right now?

Mr. SILVERMAN. You know, I will just say, a little bit like a broken record, but competitive markets because if there is the cheapest way to——

Senator HEINRICH. The market failure there is where we hear about these issues where one state in between the market that wants to sell and the market that wants to buy says no. So there has to be some sort of backstop approach to this that addresses when the market failure exists.

Mr. SILVERMAN. I think that would be great but, and here's the but. Let's take the grid as it is and say if we put an appropriate market in place and let private capital and companies fight those battles because if we say that carbon is particularly valuable in this place or that there is a, you know, a set pot of dollars that we can go out and finance against, the private capital will find a way. I mean, it's never pretty, but that's okay. And if the technology is less expensive, if wind is less expensive in one place and transmission in another, we need to have a price that lets the market——

Senator HEINRICH. If one state or one municipality, someone along the way, is not sharing in that, is not a participant in that market, they can just say no. Right now, we have a failure as a result of that.

I am curious, maybe switching gears a little bit to Mr. Majumdar, long-term storage, getting beyond the four-hour lithium-ion place that we are now. What are you most excited about? Is it compressed cryogenic air? What are you seeing in that space that is going to be the next extended, long-term, even seasonal solution to storage?

Dr. MAJUMDAR. Well, I mean, the question is a great question. What should be the cost of storage if you want to do multi-day storage which if you are at 80 percent renewables or 70 percent, you will need that.

Senator HEINRICH. Have to, yes.

Dr. MAJUMDAR. And that is on the order of about $10 to $20 a kilowatt-hour because we're not going to use it enough in cycles of it to pay it off. And that's about a factor of ten lower than lithium-ion batteries. So lithium-ion battery is not going to cut it.

Senator HEINRICH. Yes.

Dr. MAJUMDAR. And the cheapest way to store electricity at that cost level is pump hydro. And then we have compressed air. Those are scalable things.

Senator HEINRICH. Right.

Dr. MAJUMDAR. If you're looking at batteries, electrochemical batteries that are coming onboard, there are lots of very exciting things that are happening. Iron sulfur batteries, these are low cost of materials, cost of bill of material batteries. They are still in R&D. Some of them are in the pilot stage.

Senator HEINRICH. Right.

Dr. MAJUMDAR. Many of them funded by ARPA-E when I was there. And so, I think that's the pipeline that you've seen coming onboard. It's actually very positive, but we should not ignore pump hydro and compressed air.

Senator HEINRICH. Great. Thanks.

The CHAIRMAN. Thank you, Senator Heinrich.

Senator King.

Senator KING. Thank you, Madam Chair. I am loving this hearing. I really appreciate your putting it together.

A little bit of background. I spent most of my adult life in energy. I have worked, I have made my living in hydro, biomass, energy efficiency and wind, so this is very familiar to me.

The first thing I want to say is I want to match, I want to see Senator Cassidy's video and raise him by a map.

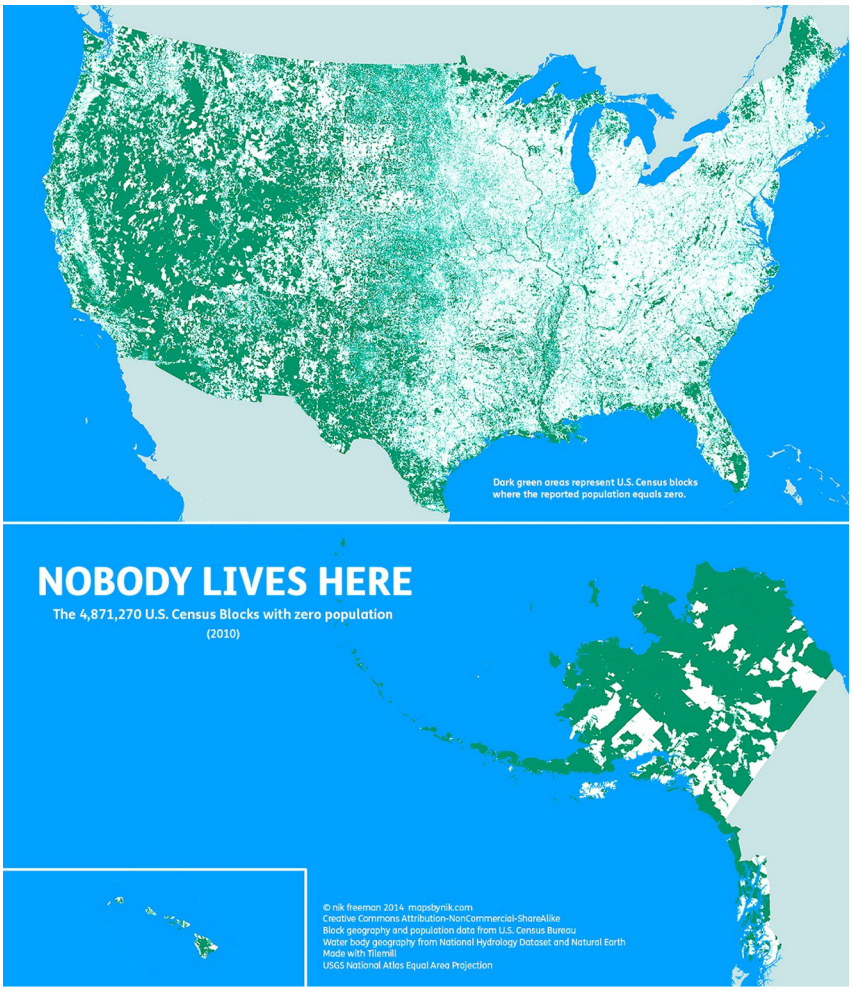
[Laughter.]

Senator KING. And the map is called——

The CHAIRMAN. We can handle maps.

Senator KING. The map is called "Nobody Lives Here."

[Nobody Lives Here Map follows.]


Dark green areas represent U.S. Census blocks where the reported population equals zero.
NOBODY LIVES HERE
The 4,871,270 U.S. Census Blocks with zero population
(2010)
© nik freeman 2014 mapsbynik.com
Creative Commons Attribution-NonCommercial-ShareAlike
Block geography and population data from U.S. Census Bureau
Water body geography from National Hydrology Dataset and Natural Earth
Made with Tilemill
USGS National Atlas Equal Area Projection

Senator KING. Forty-seven percent of the census tracks in the United States have zero population. I urge him, if he thinks we are out of room for solar and wind projects, to look down when he is flying home to Louisiana tonight. To say that there is no place for these projects to go just, you know, as much as I love the Senator from Louisiana, that just does not pass the straight face test.

Secondly, my experience in energy is there is no free lunch. Every form of energy has some drawback, some questions, some cost, whether it is environmental or economic, and I understand that.

It seems to me though that Senator Heinrich's last question, there are several really important goals here.

One is storage. Storage unlocks enormous potential for renewables. And by the way, the other place Senator Cassidy ought to look is in the Gulf of Mexico, the offshore wind has enormous potential, higher capacity factor, higher efficiency, larger turbines, less environmental impact, less neighbors impact. So, enormous potential. But storage unlocks huge potential for solar and wind.

Number two is efficiency. The cheapest, cleanest kilowatt-hour of all is the one that is not used. My experience in the energy efficiency business is the problem is energy efficiency investments have insufficient return in and of themselves at a fairly low energy cost. There has to be some subsidy. My suggestion is that utilities could pay customers to do energy efficiency which would lower their cost of acquiring new power. In other words, new energy efficiency is a "negawatt," if you will.

Carbon capture, I think, is also critical. We have this huge coal resource. We have huge energy resources. Carbon capture has got to be part of the future, it seems to me.

Number four is nuclear. I agree with you, Mr. Bryce. I think the problem I have is not, and you said something that, sort of, piqued me. Right now, it is not affordable. I mean, it just isn't. The cost per megawatt of installing a new nuclear plant is just not comparable even to any other technology and sitting next to this lady, we have to figure out what to do with the waste. It is not responsible for our generation to say we are going to solve our climate problem by building nuclear plants, and we are going to let you guys and our children and grandchildren deal with the waste. This government made a commitment to dealing with waste 70 years ago. They have not done it, and that is one of my problems with going whole hog into nuclear. But I do think, clearly, the new generation, if it comes, smaller, scalable, those kinds of solutions are important.

Number five, for me, is research and innovation. Got it, that we have all agreed on that. The shale revolution, in part, came out of research at the Department of Energy and if we can have similar research that brings us innovations like that in batteries, we are in business. I mean, that is a big deal and I think we need to appreciate that.

Finally, the point you all have made, and if you could find a question in here, by the way, you are welcome to it.

[Laughter.]

Number six is it does have to be an international solution. CO_2 does not respect boundaries. And if we do everything we possibly

can, which I think we should, but India and China do not, then we are still not going to solve this problem. By the way, to put a fine point on the problem, we are now at 410 parts per million of CO_2. First time in three million years we have been there. And the last time we were there, the oceans were 60 feet higher. I mean, to me that sort of captures where we are. So, I think, we have to be talking about all of these things.

I am a little bit worried about a carbon tax because my fear is that a carbon tax would be just high enough to be annoying and not high enough to change behavior. All the data I have seen is people, and we have lived through it, people are not going to stop driving until gas goes up a dollar or two a gallon. And nobody is talking about a carbon tax that would have that level of increase. Yet we would be taking, it is a regressive tax in a sense that we would be taking out of consumers.

You found a question. Answer.

[Laughter.]

The CHAIRMAN. Senator King, we were waiting for that question.

[Laughter.]

Senator KING. Well, I figured if I threw enough out there——

The CHAIRMAN. We were going to give you a little extra time. You found it there.

Senator KING. Yeah, okay, alright. Go for it.

Ms. LADISLAW. I was just going to offer two really quick things.

Yes, you're right, it's a well put concern about a carbon tax. It can't do everything and it can do some things and you can design it to not be regressive.

The most regressive thing about climate change is the impacts. That is absolutely the case. Everything else you can, sort of, design to be a little bit better.

And I think your point on global leadership is really important. I think if we use empirical evidence about why we're doing something and other people aren't to block action, it doesn't make answering the problem any easier.

Senator KING. No, and that is why leaving the Paris Climate Accord was a disaster because that, at least, was global leadership. It was non-binding, but at least put us out there with the rest of the world. Now we are saying to them, we are not worried about it. You do not have to worry about it.

Anyway, thank you, Madam Chair.

The CHAIRMAN. Thank you.

Senator KING. I don't usually make speeches here, you have to admit, but——

The CHAIRMAN. But this is just one of those hearings where there is a level of thought that is provoked and any time you have good thought being provoked, this is, again, this is a Committee that is taking on these issues because they demand some considered thought and, perhaps, provocative discussions.

Senator KING. Thank you for your tolerance.

The CHAIRMAN. Thank you.

Senator Barrasso, you are up next but if you would like a breather, we can turn to Senator Cortez Masto? It is your call.

Senator BARRASSO. Well, thank you very much, Madam Chairman.

The CHAIRMAN. He is ready.

Senator BARRASSO. I am ready to go, and I am very thankful to you and to Ranking Member Manchin for holding this hearing today because technological advancements have always improved our quality of life in this country and advancements in energy are certainly no exception.

When I first arrived in the Senate over a decade ago, you and I worked along with Jeff Bingaman, who was a Democrat and Chairman of this Committee, in a bipartisan way. We introduced something called the GEAR Act. Is it? Over a decade ago, a bill to——

The CHAIRMAN. What did it stand for?

Senator BARRASSO. I will tell you that in a second.

[Laughter.]

Because it was very good.

But it was designed to remove greenhouse—we have high paid staff that come up with these names and then it stands for something.

The CHAIRMAN. Yes.

Senator BARRASSO. But the idea was to remove greenhouse gas emissions from the atmosphere. We had a hearing in EPW last week about the advances in technology over the last decade to be able to do that. So it has been a big deal.

And just yesterday the Senate Committee on Environment and Public Works unanimously passed something called the USE IT Act which stands for something different. Again, it is bipartisan, it is bicameral—it promotes carbon capture, utilization, and storage.

Certainly there is a lot of momentum behind carbon capture and I really look forward to working with both of you and all the colleagues to quickly pass this kind of legislation to promote the development of carbon capture technologies. As we continue to pursue carbon capture and other innovations to address greenhouse gas emissions, I think it is important that all discoveries, all findings and failures are shared throughout the research community so people can know what worked, what did not work and where we ought to be then focusing the next level of research.

So in the past, federal research has not always been available to private researchers. I had a visit with Bill Gates, and he was trying to say how do you get more information? How do we get shared information? And I think sometimes this lack of communication among researchers presents a risk of duplicating ongoing efforts. You are shaking your heads up and down so I will start, maybe run the panel. How do we ensure transparency among researchers to ensure that we do not waste time and money, both are critical resources, with how we spent this on complementing each other on improving the research instead of duplicating it?

We will run down the panel.

Dr. MAJUMDAR. Sure. As I said before, having been the first Director of ARPA-E and then also the Acting Under Secretary with all the applied energy programs, I think there's tremendous value in looking at increasing the budget. We had an ARPA-E hearing where I said that the ARPA-E budget ought to be on the order of $1 billion.

But also look at the effectiveness, not just of ARPA-E but the applied energy program, Basic Energy Sciences. I think that's the fundamental base, the foundation of everything. We have to look at how our entrepreneurial spirit is ignited with this.

I think creating market demand, we talked about this earlier as well, of how, you know, I'm from Silicon Valley and people think that Silicon Valley was created by the venture capitalists. That's wrong.

It was created because the Department of Defense wanted to buy things of new technologies. And I think we should be looking at the biggest energy user in the country which is the U.S. Government, to see how to look at energy efficiency in buildings, new kinds of fuels, new electrification of batteries so that these technologies come down on the cost curve and become competitive, not just in the United States, but around the world.

So I think there's a whole—we have to look at it holistically, not just innovation out here, policy over there, just combining.

Senator BARRASSO. And to that point, in a second, Mr. Silverman.

If you cannot do it worldwide the impact is nothing because emissions in the United States are actually going down where they are going up in China and in India and around the world. But if you shut off the United States completely, it would not make the kind of——

Dr. MAJUMDAR. It's a $10 trillion per year export market that we're talking about, because the rest of the world is looking for technology.

Senator BARRASSO. Sure.

Mr. Silverman?

Mr. SILVERMAN. I love the order we're going in because we're the customers who take the technology that ARPA-E and others develop and then we, sort of, take it to the next stage whether it's through something like the carbon capture system down at Parish or the Ivanpah facility which is the largest concentrated solar facility in the world, but we also take a lot of other technologies.

And you know, I love going to pitch meetings with people who come out of ARPA-E because they always have such fascinating ideas. And you know, the thing that we often lack, the thing that prevents us from taking those and really running with them and making them commercial isn't the technology. It's the lack of a comprehensive, long-term price signal because it's really hard to take capital and deploy it if you don't know what the market is going to look like if you don't have a financeable price signal that you're being sent.

And so, a lot of this, you know, I almost don't care what the technology of the future is, because a competitive market that sends the right price signal and says, hey, we want more of this attribute and we're willing to pay for it. That will get at the right technology. And so, when we think about it, that's what we're looking for and that's what we really lack in today's markets.

Senator BARRASSO. Ms. Ladislaw?

Ms. LADISLAW. I thought Secretary Moniz and Secretary Dabbar both had great ideas about how to increase transparency and cooperation within the research structure.

Just as a simple observation, I think anything that's like an XPRIZE or a grand challenge or something that, sort of, organizes researchers against a challenge, kind of just naturally brings out what are people doing relative to one another and draws in the private sector. So I think more things like that are really proven to be quite effective.

Senator BARRASSO. That is exactly what the GEAR Act was about, a gear, an XPRIZE to make carbon productivity.

And—yes?

Mr. SANDALOW. Three points, Senator.

First, engage globally. You're 100 percent right. There's no solution to this problem unless we do that. That means not just being part of the Paris process, but engaging robustly in the Paris process. It means participating in other processes, like the Clean Energy Ministerial, that help to disseminate these technologies around the world.

Second, plan. Planning is a real gap in this country. Other countries do a much better job than we do. And having served as Acting Under Secretary at the Department of Energy, I think the applied programs working with Congress can do a much better job of long-term planning with assistance from Congress.

And then third, deploy. There is no long-term, real cost reduction for many of these technologies unless they're being deployed in the private sector. We need the policy framework that gets them out into the marketplace.

Senator BARRASSO. Mr. Bryce?

Mr. BRYCE. Yes, sir, Senator. I'll give you a slightly different answer.

I think these energy technologies are diffusing around the world with remarkable speed without much government assistance.

Just finished shooting a documentary called, "Juice: How electricity explains the world." I was in Lebanon about 18 months ago. I was in the Chouf Mountains, southeast of Beirut, and I saw 100 kilowatts of Chinese solar panels that were capturing Lebanese sunlight that was being stored in lead acid batteries that were designed in Bulgaria and manufactured in India. So there's a robust international marketplace for all kinds of energy technologies, and in my view, these are diffusing very rapidly because there's a market for them.

Senator BARRASSO. Thank you.

Mr. SANDALOW. If I could, Senator?

That cheap solar panel is cheap because the German government over the course of ten years deeply subsidized the purchase and the Chinese government deeply subsidized solar manufacturing and because this government, over the course of many years, was a leader in research and a variety of other government factors. So to say that solar panels are deploying around the world because governments are staying away is not really the full story.

Senator BARRASSO. Madam Chairman——

Mr. BRYCE. I'll just say that's not my point.

Senator BARRASSO. Regrettably, my time is expired.

But Madam Chairman, just to tickle both of our memories, the GEAR Act stood for Greenhouse Gas Emissions Atmospheric Removal Act, and I submit that as part of the record.

[Laughter.]
[Details of the GEAR Act follow.]

110TH CONGRESS
2D SESSION

S. 2614

To facilitate the development, demonstration, and implementation of technology for use in removing carbon dioxide and other greenhouse gases from the atmosphere.

IN THE SENATE OF THE UNITED STATES

FEBRUARY 8 (legislative day, FEBRUARY 6), 2008

Mr. BARRASSO introduced the following bill; which was read twice and referred to the Committee on Environment and Public Works

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A BILL

To facilitate the development, demonstration, and implementation of technology for use in removing carbon dioxide and other greenhouse gases from the atmosphere.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the ''Greenhouse Gas Emission Atmospheric Removal Act'' or the ''GEAR Act''.

SEC. 2. STATEMENT OF POLICY.

It is the policy of the United States to provide incentives to encourage the development and implementation of

technology to permanently remove greenhouse gases from the atmosphere on a significant scale.

SEC. 3. DEFINITIONS.

In this Act:

(1) COMMISSION.—The term ''Commission'' means the Greenhouse Gas Emission Atmospheric Removal Commission established by section 5(a).

(2) GREENHOUSE GAS.—The term ''greenhouse gas'' means—

(A) carbon dioxide;

(B) methane;

(C) nitrous oxide;

(D) sulfur hexafluoride;

(E) a hydrofluorocarbon;

(F) a perfluorocarbon; and

(G) any other gas that the Commission determines is necessary to achieve the purposes of this Act.

(3) INTELLECTUAL PROPERTY.—The term ''intellectual property'' means—

(A) an invention that is patentable under title 35, United States Code; and

(B) any patent on an invention described in subparagraph (A).

(4) SECRETARY.—The term ''Secretary'' means the Secretary of Energy.

SEC. 4. GREENHOUSE GAS EMISSION ATMOSPHERIC REMOVAL PROGRAM.

The Secretary, acting through the Commission, shall provide to public and private entities, on a competitive basis, financial awards for the achievement of milestones in developing and applying technology that could significantly slow or reverse the accumulation of greenhouse gases in the atmosphere by permanently capturing or sequestrating those gases without significant countervailing harmful effects.

SEC. 5. GREENHOUSE GAS EMISSION ATMOSPHERIC REMOVAL COMMISSION.

(a) ESTABLISHMENT.—There is established within the Department of Energy a commission to be known as the ''Greenhouse Gas Emission Atmospheric Removal Commission''.

(b) MEMBERSHIP.—

(1) COMPOSITION.—The Commission shall be composed of 11 members appointed by the President, by and with the advice and consent of the Senate, who shall provide expertise in—

(A) climate science;

(B) physics;

(C) chemistry;

(D) biology;

(E) engineering;

(F) economics;

(G) business management; and

(H) such other disciplines as the Commission determines to be necessary to achieve the purposes of this Act.

(2) TERM; VACANCIES.—

(A) TERM.—A member of the Commission shall serve for a term of 6 years.

(B) VACANCIES.—A vacancy on the Commission—

(i) shall not affect the powers of the Commission; and

(ii) shall be filled in the same manner as the original appointment was made.

(3) INITIAL MEETING.—Not later than 30 days after the date on which all members of the Commission have been appointed, the Commission shall hold the initial meeting of the Commission.

(4) MEETINGS.—The Commission shall meet at the call of the Chairperson.

(5) QUORUM.—A majority of the members of the Commission shall constitute a quorum, but a lesser number of members may hold hearings.

(6) CHAIRPERSON AND VICE CHAIRPERSON.—The Commission shall select a Chairperson and Vice Chairperson from among the members of the Commission.

(7) COMPENSATION.—A member of the Commission shall be compensated at level III of the Executive Schedule.

(c) DUTIES.—The Commission shall—

(1) subject to subsection (d), develop specific requirements for—

(A) the competition process;

(B) minimum performance standards;

(C) monitoring and verification procedures; and

(D) the scale of awards for each milestone identified under paragraph (3);

(2) establish minimum levels for the capture or net sequestration of greenhouse gases that are required to be achieved by a public or private entity to qualify for a financial award described in paragraph (3);

(3) in coordination with the Secretary, offer those financial awards to public and private entities that demonstrate—

(A) a design document for a successful technology;

(B) a bench scale demonstration of a technology;

(C) technology described in subparagraph (A) that—

(i) is operational at demonstration scale; and

(ii) achieves significant greenhouse gas reductions; and

(D) operation of technology on a commercially viable scale that meets the minimum levels described in paragraph (2); and

(4) submit to Congress—

(A) an annual report that describes the progress made by the Commission and recipients of financial awards under this section in achieving the demonstration goals established under paragraph (3); and

(B) not later than 1 year after the date of enactment of this Act, a report that describes

the levels of funding that are necessary to achieve the purposes of this Act.

(d) PUBLIC PARTICIPATION.—In carrying out subsection (c)(1), the Commission shall—

(1) provide notice of and, for a period of at least 60 days, an opportunity for public comment on, any draft or proposed version of the requirements described in subsection (c)(1); and

(2) take into account public comments received in developing the final version of those requirements.

(e) PEER REVIEW.—No financial award may be provided under this Act until such time as the proposal for which the award is sought has been peer reviewed in accordance with such standards for peer review as the Commission shall establish.

SEC. 6. INTELLECTUAL PROPERTY CONSIDERATIONS.

(a) IN GENERAL.—Title to any intellectual property arising from a financial award provided under this Act shall vest in 1 or more entities that are incorporated in the United States.

(b) RESERVATION OF LICENSE.—The United States—

(1) may reserve a nonexclusive, nontransferable, irrevocable, paid-up license, to have practiced for or on behalf of the United States, in connection with

any intellectual property described in subsection (a); but

(2) shall not, in the exercise of a license reserved under paragraph (1), publicly disclose proprietary information relating to the license.

(c) TRANSFER OF TITLE.—Title to any intellectual property described in subsection (a) shall not be transferred or passed, except to an entity that is incorporated in the United States, until the expiration of the first patent obtained in connection with the intellectual property.

SEC. 7. AUTHORIZATION OF APPROPRIATIONS.

There are authorized to be appropriated such sums as are necessary to carry out this Act.

SEC. 8. TERMINATION OF AUTHORITY.

The Commission and all authority of the Commission provided under this Act terminate on December 31, 2020.

○

The CHAIRMAN. That is worthy of submission. We will have to re-up that one.

[Laughter.]

Thank you, Senator, and I appreciate the exchange here.

Senator Cortez Masto.

Senator CORTEZ MASTO. Thank you.

First of all, let me thank the Chairwoman and the Ranking Member for this great discussion, so appreciated. And thank you all for being here.

I am from Nevada and let me just say I appreciate the conversation—not just about the solar and the wind but we have geothermal, we have hydropower. That is an important part of our energy portfolio.

Let me ask you this because I do not disagree with what I hear today. I think we are all, kind of, talking about the same thing which is you can have a diverse energy portfolio but our stated outcome with that is to reduce our carbon footprint. Would you all agree with that? Yes? Yes, everyone is nodding their head yes.

Dr. MAJUMDAR. And affordability.

Senator CORTEZ MASTO. And affordability, correct, right. But that is the ultimate goal here.

Let me ask you this—and because we have pulled out of the Paris Climate Exchange, because we are not engaging globally now—do you think this country, the United States, should not or stop reducing its carbon footprint? Does anybody believe that? I don't think anybody agrees with that.

Mr. SANDALOW. It's absolutely imperative that we continue to reduce our carbon footprint and that the whole globe do that.

I mean, we've talked a little bit in this area, not a lot, about the urgency of climate change. I mean, we are already experiencing the dangers of climate change. It's unbelievable the amount of flooding, severe storms, fires that we've experienced in this country and around the world. Unless we jump on this problem now, those risks are going to be even worse in the decades to come.

Senator CORTEZ MASTO. Right, and I agree. I think we can lead, and this country should be leading in this direction.

The other thing is, I think at a federal level, we should be investing at a federal level in this new technology. ARPA-E is incredible where I think there is that partnership between the Federal Government and the private sector.

I guess my question for you, and I am going to butcher your name, Doctor, Dr. Majumdar?

Dr. MAJUMDAR. That is perfect.

Senator CORTEZ MASTO. Thank you, sorry.

In your testimony you mentioned a handful of potential innovative solutions to address climate change such as grid-scale storage, modular nuclear reactors, we have talked about that, decarbonizing, industrial heat processes and others. Can you discuss the intersection of what is needed from a policy perspective to ramp up such technologies and how can we better facilitate the development in them and deployment?

Dr. MAJUMDAR. Senator, that's a great question, and I think we have to look at it holistically.

It is absolutely critical to invest in the research, this foundational science and energy research, that the Department of Energy invests in and support them. It's also very important to get the right people in the Department of Energy to be the best stewards of this and that depends, of course, on the Executive Branch.

I think it is also important to create, as was discussed, the markets for these new technologies, otherwise it's very difficult for these new technologies to be able to get in there because they need a little bit of health initially.

And whether it's a price, whether it's standards, I think we can discuss that, but I think we need some kind of pull on the other side of the value chain. In between, we need infrastructure. And I think, I can't overemphasize how important that is.

There was a question from Senator Heinrich about transmission lines. We are not very good at building transmission lines. That requires the Federal Government and the state governments and the local jurisdictions to partner together to expedite and streamline this process. Otherwise, we can put all the wind farms up but if you can't get the electricity to the places where the people live—it's all about the people at the end of the day——

Senator CORTEZ MASTO. Right.

Dr. MAJUMDAR. ——then we are not doing a good job. It's not optimal.

So I would say paying attention to the infrastructure, paying attention to the capital requirements to build infrastructure, to bring in private capital, to use the federal dollars to be able to leverage and maybe create a little bit of a competitive spirit amongst the states who can deliver. And that's the kind of way to draw that in, to bring in these new technologies, test them out, put them, deploy them and then if you can lead that in the world, that creates the international market where everyone is looking for technologies in the future.

Senator CORTEZ MASTO. Thank you.

Thank you. Thank you to the panel. I appreciate the conversation this morning.

The CHAIRMAN. Thank you.

This has been good discussions and good debate going on. There has been a little bit of discussion on the efficiency side. I think you pointed out in your monologue there or soliloquy or whatever it was.

Senator MANCHIN. It was in there somewhere.

The CHAIRMAN. It was in there somewhere.

But the focus that what we do not spend is, in fact, probably our wisest energy source here.

This is not a budget hearing, but we have been in the midst of budget hearings. I am on the Approps Committee, so we have been looking critically at those parts of the budget, whether it is in DOE or other parts, where I think we can be making a difference when it comes to our missions.

When I see programs such as the Weatherization Assistance Program being zeroed out, it just causes me to, I guess there is a level of frustration there because it is seemingly the easy things. Maybe it is because we think we do not need to be doing the easy things anymore.

We talk a lot around here about let's go after the low-hanging fruit, and I think sometimes we think that if it is too small we are not making a difference, we have not addressed the urgency of now that you all speak to.

Can you share with us your observations in this regard that doing a little bit every day, maybe this incremental, I think you said, Ms. Ladislaw, moderate climate policy need not be mediocre which I think is well said.

But we are kind of dealing with the rhetoric around here. We have a Green New Deal that is out there that is going to be everything to everybody. We are going to be 100 percent renewable in a couple decades. It makes it all sound so easy. Then people come to us and say, well why haven't you made it happen? So some of this is about managing expectations while at the same time we are pushing ourselves on a daily basis.

But can we have a couple minutes of discussion about why it is also important not to overlook the smaller, more incremental things that clearly are making a difference there? And I throw it out to any of you.

Mr. SILVERMAN. I'll go ahead and start.

I love energy efficiency because it is such a cost-effective, commonsense, you know, it's what I tell my daughter, right? Shut the light off when you leave the room.

The CHAIRMAN. It's what everybody can contribute.

Mr. SILVERMAN. Absolutely.

But here's the business model challenge that my company faces when we try to drive energy efficiency spend because we go in and we're competing with the utility monopoly and they don't want to give us access to the meters. They don't want to give us access to the customers. We can do on bill financing of energy efficiency improvements.

These problems actually have been solved in one state which is Texas where they actually have really restricted the utility to being the monopoly utility to being the poles and wires company and the rest of us are out there in the market doing really crazy, fun, interesting energy efficiency retail demand response products.

We actually compete with other competitive suppliers on who has the best rate for retail demand response, you know, where we send out a text message and if you reduce your electricity over the next hour, you get paid.

I mean, these are the kind of innovative products, but really outside of Texas, our ability to compete to provide those products and take them to consumers and market to consumers is either restricted or entirely non-existent.

The CHAIRMAN. Go ahead.

Mr. SANDALOW. Senator, my favorite energy efficiency investment are white roofs, cool roofs. They are so simple and so cheap and so low tech, but in warm climates, simply painting your roof white will save a lot in terms of air conditioning. Some places do it, some places don't. There are lots of other examples of that type of investment that we can make.

Senator MANCHIN. How about black roofs in real cold areas?

Mr. SANDALOW. Don't know if that helps, Senator.

The CHAIRMAN. Well, I do know that it has impact on the wind turbines, the color that you paint the blade to keep them from icing is darker blades.

Mr. SANDALOW. It's just a great example of the type of simple changes that we can make. And you know, I think we also need to be doing leading R&D on things like carbon fiber materials that are very lightweight that can be used in vehicles to save energy. I mean, there's lots of high-tech research to be needed, but also just some very simple things we can do and government policies can help to push those out into the marketplace.

The CHAIRMAN. Ms. Ladislaw?

Ms. LADISLAW. So, just very quickly on the psychology of the issue, right?

We're not going to be done with this climate problem, right? So the idea that we do a thing and that it's solved, we're behind. And the volume and the magnitude of the Green New Deal isn't wrong, we're just that behind.

But we need to do like an improv class approach, right? A lot less of the "no, but" and a lot more of the "yes, and" because we just have to build momentum. That's really key to a lot of these solutions.

So on energy efficiency it really does make a lot of sense. It is one of those areas where a price on carbon may not, doesn't make that much of a difference and you know, when we have the government shutdown, right? We really learned how very close the American public lives to not having enough money to pay their bills. Even if efficiency makes sense, they don't have the cash to do it.

So if we're going to make, sort of, you know, progress on some of those issues, we need to have this consistent, let's learn from what has worked, let's learn from what hasn't worked and let's keep going and sort of keep revisiting these things because if we're going to re-engineer the entire economy to be net zero if we're going to tackle the carbon management side of this problem. And that's not resilience. So yes, and keep doing stuff that's working, revisit it on a regular basis. The small stuff really does add up.

The CHAIRMAN. Senator Manchin, do you want to step in?

Senator MANCHIN. I just want to say that first of all, I appreciate it, this has been a wonderful, informative discussion that we have had. I think you have been so helpful, and I think everyone on this Committee has enjoyed it that has been here.

I am going to take my State of West Virginia. We are still producing 91 percent of our power from coal-fired units. Nothing has changed except the prices have gone up for some of the most challenged incomes of people anywhere. They are on the front end. They get beat up unmercifully and all we have done is drive the price of coal-fired plants to the point to try to make our renewables look more competitive and it is just causing a tremendous hardship. We were so attractive to industries in manufacturing because we were in the four-cent category per kilowatt-hour. We are up to six and eight and ten cents now in the commercial arena. We used to be at six and eight cents in residential. We are at 12. We are up to the national average.

That is what you cannot sell. And you want to know why we lose the rural areas? It makes no sense to them. Why are you punishing the people who have done the heavy lifting?

Mr. Bryce, I think you are an all-in energy person, but you are very pragmatic about your approach. If we are going to do something, let's do it and don't dillydally around. I think my good friend, Angus King, says there's still an awful lot of energy property that he can put a lot more renewables on. That is fine, but I understand the grid system is not there to deliver what you can produce in those empty areas and that cost would be pretty extravagant.

What is the quickest solution, is nuclear? Bill Gates is giving me the same kind of spiel you have given me on what he is trying. Bill Gates says, listen, Joe. He said everybody talks a good game. I put my money where my mouth is. I have spent billions. I can tell you what works and doesn't work. I can tell you what is aspirational and what is doable. And he is big on this nuclear, but like you said, speaking of Catherine Cortez Masto, our Senator, she says, why do you keep pushing it on me? Why is it Nevada? Why is it Yucca Mountain? Where are we going to get rid of this stuff? And it lasts for eternity, so?

Just give me a real quick response on where you stand on what you think is the quickest change we can make within that ten-year window. Use the ten-year window.

Mr. BRYCE. Well, I think in the ten-year window I think it's going to be U.S. exports of natural gas that are going to make the biggest effect on decarbonization.

There was a report recently out of Singapore that Shell has offered a Japanese company to supplant the coal-fired power plant, that they want to provide them with a long-term LNG contract. So, the maturation of the global LNG market is——

Senator MANCHIN. They are going to take a coal plant that has a lot of use of life?

Mr. BRYCE. The proposed coal plant would not be built, instead it would be supplied by natural gas.

Senator MANCHIN. Okay.

Mr. BRYCE. In Japan.

But my quick response overall, Senator, is I'm incredibly optimistic. I'm a humanist. I've been traveling the world the last three years looking at what's going on. The prize for companies that create key innovations, yes, government policy can have an effect, but the global energy market is a $5 trillion a year business. And so, the U.S. Government can affect policy, but those policy results are going to be limited.

And I'll just end with this. Again, this is not just a U.S. issue. There are three billion people, roughly today, in the world who use less electricity than my kitchen refrigerator. So, the defining inequality in the world today is about electricity and energy poverty and these countries that in India, Lebanon, places I visited, they are not going to sit around and say, well yes, we may want clean energy, but we want electricity now.

Senator MANCHIN. Well, rural India is a good example.

Mr. BRYCE. Exactly.

Senator MANCHIN. They don't care what comes out of the smokestack.

Mr. BRYCE. Or they're relying on diesel or fuel oil-fired generators which are expensive but, in many cases, that's their only option.

Senator MANCHIN. Yes.

The CHAIRMAN. Welcome to rural Alaska where so many of our villages are still powered by diesel-powered generation. That is it. They get their fuel brought in by barge twice a year and some years they do not judge correctly how cold and how long that winter is going to be, so they run out of fuel in February. The river is still locked in with ice.

How do they get their fuel? It is flown in 50-gallon barrels at a time.

So if you do not think it is already costly enough—to be locked into a fuel price that was set eight months prior and you have full transportation costs coming from the Lower 48 up the coast and up into the Yukon. But what is your alternative? What is your alternative?

And so, as difficult as it is in many parts of the world that we would consider Third World countries, when we talk about energy poverty, Alaska is poster child for the land of riches and abject poverty when it comes to meeting energy needs. That is why we feel like we're the incubator of some really cool and innovative ideas, because when I can go out to a village like Kwigillingok, you have 400, 500 people in there. They have been powered by diesel for as long as anybody in that village can remember. They have a couple wind turbines that are clicking along. A little bit of a storage facility. It looks like a couple outhouses put together, lifted up off the tundra that you go inside, looks like little Chevy Volt batteries that are there, probably nothing more sophisticated than that. And on the day that I was there, everyone says, can you hear that? I am like, I cannot hear anything. And they said, that is the point. The generators are off. The generators were off for three days of quiet. And for that community, it was life changing.

And so, incrementally, in little bits and pieces, this is where I get so excited about microgrids and thank you, Dr. Majumdar, for your leadership when we had National Lab Day up in Fairbanks last year. You saw some of the innovation that not only is going on within our national labs but what is going on within our living laboratories up north with these microgrids, what we are able to do. Sometimes it is not even engineers, it is people that just know how to fix an engine. And they are working good ideas, a little bit of duct tape and some rope and it is amazing what you can make happen.

Senator KING. Madam Chair, in Maine we call those people the guy you call when the horse falls down the well.

[Laughter.]

That is native engineering skill.

The CHAIRMAN. I will remember that. We do not have a lot of horses that might fall into the well.

Senator KING. Okay, the moose.

The CHAIRMAN. The moose that falls into the well.

[Laughter.]

Thank you all. This has been very, very interesting and provocative and helpful to us.

Know that we will count on you as resources as we continue our discussion, but I appreciate each of you and what you have helped fill the record out.

With that, the Committee stands adjourned for yet another fun return to the Energy and Natural Resources Committee.

[Whereupon, at 11:58 a.m. the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

U.S. Senate Committee on Energy and Natural Resources
April 11, 2019 Hearing: ***Opportunities for Energy Innovation and Other Potential Solutions to Help Address Global Climate Change***
Questions for the Record Submitted to Dr. Arun Majumdar

Questions from Chairman Lisa Murkowski

Question 1: You are clear in your belief that improving the energy efficiency of buildings is an opportunity to reduce emissions. In your written testimony, you point out that buildings today consume 40 percent of our primary energy and 75 percent of our electricity.

- How can we account for the unique Arctic challenges when we are determining the best way to capture the energy efficiency gains and emissions reductions available to us in the building sector?
  I believe this deserves a multi-pronged coordinated approach. I also think this can potentially form the template, at least a partial one, of what could be used in other regions of the US as well.

  Technology: The largest fraction of the energy demand in most Arctic regions is heat. As Alaska introduces emissions-free electricity from wind, solar, or hydroelectric, it can be utilized for thermal management through the use of heat pumps. This is necessary but not sufficient. Technologies for efficient thermal utilization such as heat storage, high-performance heat exchangers manufactured locally by 3-D printing (additive manufacturing) and whole-building thermal systems design could lead to significant increases in energy efficiency. These would reduce the demand for fuel supply chain and empower people in the Arctic region with technologies that utilize local resources, and create a pathway towards self sufficiency[†].

  The National Laboratories (NLs) and the DoD along the local Universities (e.g., University of Alaska, Fairbanks) and energy service companies would be the ideal partners for help with technical expertise and techno-economic analysis for the best possible energy efficiency outcomes. Given the widespread use of communications technology, the NLs could help monitor the energy performance of buildings in real-time and create a data repository hosted by University of Alaska, which could prove to be important in understanding on-the-ground challenges and continuously assess and improve energy efficiency over time.

  Financing: Energy efficiency ought to save money in the long-run. However, it often needs financing for upfront cost and some on-going maintenance. The goal should be to reduce the pay-back period to roughly 2-5 years, which will make it attractive for investors and energy efficiency businesses such as energy service companies. This requires techno-economic knowledge and analysis as well as certainty of energy savings. Here again, the NLs could provide technical expertise. The NLs' role in real-time monitoring/commissioning and the data repository would be very important, because it could provide the certainty of energy efficiency gains, which is traditionally highly uncertain (and therefore risky) without any

[†] If socially accepted, one could even consider trash-can-sized small modular nuclear reactors (e.g., Oak Ridge National Lab and Oklo Inc. are developing such reactors), although utmost care should be taken to manage the fuel cycle.

measurements. Consequently, this would provide certainty in financial returns and therefore make it easier for financing.

Policy: For urban Arctic areas, it is very important to provide benchmarks and targets for energy performance in terms of kBTU/sq.ft-year separately for heat and electricity. These should be bare minimum efficiency performance standards that the energy service companies be required to achieve. The continuous performance monitoring by the NLs should provide validation for achieving these performance targets. While there are voluntary standards offered by ASHRAE and other organizations, this should be either mandatory or come with some financial incentives to those willing to adopt the performance-based standards as opposed to adoption of only building codes, which are for design and not for operation.

- Are there opportunities for the federal government to make better use of local entities like the Cold Climate Housing Research Center, who already have the necessary local knowledge, cultural expertise, and relationships to be effective, in Fairbanks, Alaska?
  The Cold Climate Housing Research Center in Fairbanks is an ideal "hub" that brings together on one hand the in-house technical expertise as well as those in National Laboratories and DoD, and on the other hand the local knowledge of the culture and needs of the Alaskan people. This "impedance matching" that CCHRC can provide will play a vital role in educating the NLs and DoD about the needs of the Alaskan people, so that their contributions can be easily and rapidly translated into real-world practical solutions in Alaska.

  The CCHRC should also offer educational experience for local Alaskans not only on the technical aspects of energy efficiency, but also on the business aspects and entrepreneurship. This local empowerment could lead to new local business creation.

Question 2: As you know, the Master Limited Partnership Parity Act you discuss in your written testimony would create avenues for master limited partnerships use with renewables, but not nuclear.

- Do you have any thoughts on how nuclear could be incorporated in that type of policy?
  I feel that nuclear should be included in the MLP Parity Act and that the current version should be amended for this inclusion. The MLP Parity Act should provide true parity and a level playing field for low-cost financing with an "all of the above" strategy, and let these technologies compete in the market place on an equal footing.

- Do you have other creative ideas regarding the mechanisms to deploy advanced clean energy technologies?
  Advanced and innovative clean energy technologies that are new in the market have the disadvantage of being considered a risk from financing viewpoint, even though they may be less expensive and cleaner than the incumbent. This is partly because risk aversion is systemic in the energy sector. Since the federal and state governments are the largest users of energy in the USA, the government could take the lead to provide the first market for affordable advanced

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clean energy technologies. Furthermore, non-profit enterprises such as Universities, churches, public schools, county hospitals and other similar organizations could also join to provide the first market. This assurance of a market would offer "bankability", which would not only de-risk advanced technologies, but also enable them to access long-term low-cost financing, which could otherwise be either prohibitive or be burdened with much higher cost of capital.

Questions from Ranking Member Joe Manchin III

Question 1: As the number one funder of clean energy R&D, the Department of Energy (DOE) plays a critical role in the innovation process, from early-stage research all the way to testing and deployment. A number of changes to improve DOE have been made over the years by Congress or the Executive Branch. Former Energy Secretary Ernest Moniz made the case before the Committee that DOE's organization by fuel-type is stifling innovation. I have requested that the Government Accountability Office review the DOE's R&D efforts to get a better understanding of what's working, and where there is room for improvement in DOE's efforts to commercialize much-needed technologies.

What organizational barriers can you identify at DOE?

What ideas do you have on what we can do, structurally, to get technologies successfully through the valley of death?

I am glad this issue has been raised. Having served in the DOE as the Founding Director of ARPA-E and simultaneously as Acting Undersecretary of Energy with Secretary Chu, and also as the Vice Chair of Secretary Moniz's advisory board, I have witnessed this first hand. To partly address this, I had helped Secretary Chu introduce DOE-wide cross-cutting teams such as Sunshot (for solar), Grid Tech Team (for electricity infrastructure), Storage Tech Team, etc. The purpose of these cross-cut teams was to bring together the relevant people from the Office of Science, Applied Energy Offices and ARPA-E to create a "one DOE" vision in each of these areas, which is achieved via internal DOE coordination on technical goals, budgets, as well as the R&D and industrial communities in each of these sectors. These were universally appreciated and applauded by both the OMB and the Congress. I was glad to see that Secretary Moniz and Undersecretary Orr not only built on these cross-cuts, but also created new ones. Hence, to reduce the barriers and potentially "silos" of efforts within the DOE, I would strongly recommend that at the very least, the DOE should continue these cross-cuts. But DOE can do much more.

On one hand, the DOE organization is framed largely around R&D and not as much around demonstration project. And when there are demonstration projects are run by the Applied Energy Offices, the role of the private sector needs revisiting. On the other hand, the DOE loan guarantee program evaluates applications from the private sector and provides financing to energy projects, which are often those where the technology risk has been substantially reduced and it is business ready, i.e. there are guaranteed revenue streams such as power-purchase agreements. The DOE is not well geared up for demonstration projects, where new technologies are tested in a market context, and de-risked in the

process so that it becomes bankable. This is where the engagement between the DOE and the private sector needs to be revisited.

It is my opinion that when new technologies undergoes a "demonstration", the private sector needs to have skin in the game because they would be direct beneficiaries of the de-risking process. To address this issue, I would urge you to consider an article (see Appendix) that a few of us co-authored, entitled "Energy Innovation Needs a Private Sector Push" by Arun Majumdar, John M. Deutch, Norman R. Augustine and George P. Shultz, *Bloomberg*, Feb 11, 2016. Following this, the DOE could convene the private sector and create industrial consortia (e.g., SEMATECH), whereby a small amount of DOE funding (about 10-15%) could catalyze a group of companies (perhaps along a supply chain) to come together and take a private-sector approach to demonstration projects. They would make 85-90% of the financial contributions so that they can share the risks, the costs and the rewards without onerous government involvement.

It is hard to overstate the advantages that a private sector innovation project has over a project supported by the DOE for late-stage demonstration programs. Federally-sponsored demonstration projects involve many specific rules and regulations that impose extra cost and time requirements. There are cumbersome restrictions on procurement practices, requirements for cost and performance reports, and significant uncertainties on the timing and amount of contract payments, let alone consistent Congressional backing. Not surprisingly, for a variety of reasons – changing priorities; shifting markets; Congressional influence; underfunding of projects; and lack of professionals with adequate market, finance, and management experience – DOE's record, with a few exceptions, in downstream technology demonstration has been mixed. The difference in how a federally supported and private sector technical development programs are run is so great that private investors and their banks find it difficult to evaluate confidently in the former case if required investment criteria have been demonstrated. A private sector innovation project, if successful, is more likely to result in deployment of technology than a federal innovation project.

The DOE could play the role of catalyzing such consortia of industry and state/local governments (or Energy Innovation Entities described in the Bloomberg article) through a competitive funding process, whereby the DOE funding could be about 10-15% with the rest coming from the private sector.

Question 2: Engaging the private sector in energy innovation through various types of partnerships with the Department of Energy or National Labs will be critical going forward. The federal government can be a catalyst because of its convening authority and it can provide matching funds. For example, DOE's Energy Innovation Hubs have received a lot of attention and seem to generally be a good model for pooling public and private sector multi-year investments.

How do you think we can best leverage DOE and National Lab capabilities and funding in the private sector?

And how do we focus these efforts on the highest priority areas needed to achieve a clean energy economy?

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When I was the Vice Chair of Secretary Moniz's advisory board (SEAB), I led the National Lab Task Force, which produced a report[‡] that directly addressed the issue raised in this question: How can the DOE and the National Labs provide value for the private sector? Here are the main conclusions and recommendations:

1. The scientific user facilities and the scientific talent in National Labs (NLs) are of immense value to the private sector, which can help form a nucleus and local hub for innovations.
2. This value of NLs is most leveraged through long-term partnerships between the NLs and the private sector. Large businesses, who can afford to take a long-term perspective, are the biggest beneficiaries of NL facilities and talent. An example is the Combustion Research Facility at Sandia, the Synchrotron facilities at Argonne, LBNL, Brookhaven and SLAC, but there are many others.
3. Small businesses, who tend to have a shorter-term outlook and prefer to move faster, find it more difficult to work with the NLs. This is especially because the research agreements such as CRADAs and Work for Others (WFOs) or Strategic Partnerships require approvals from the DOE headquarters, which can often be time consuming. There is a significant opportunity cost in not being able to fully engage the most dynamic and risk-taking aspect of the innovation ecosystem - small businesses.
4. To address #3, the NL report recommended Secretary Moniz to:
    a. Streamline and expedite the DOE approval process
    b. Give authority to the NL Directors to make partnership decisions for dollar values lower than a threshold, so that decisions can be made faster and based on local considerations. This can be done under DOE guidelines so that DOE policies are adequately addressed but the decision-making process is distributed and not centralized for small dollar-value engagements.
5. The address #3, the NL report recommended NL Directors to:
    a. Consider leave of absence programs for NL scientific personnel to transition to the private sector for brief periods (2-3 years) and provide the assurance of research funding when they return. This would bring parity to University practices, which have created innovation ecosystems in close proximity around universities.
    b. Consider creating innovation programs such as Cyclotron Road at Lawrence Berkeley National Lab that recruits and nurtures scientific talent in small businesses within the boundaries of the NLs, and thereby allow them to use the NL scientific facilities and collaborate with the NL scientific staff. This has now been started at Oak Ridge National Lab and Argonne National Lab. There is no reason why this cannot be started at other NLs. In fact, Congress should consider fellowship funding to support this scientific talent when they first launch into such programs, allowing them to compete for DOE research funding as well as private sector investments.
    c. Consider local innovation programs such as Cyclotron Road focus on the local needs and leverage the local talent in the NL. For example, an innovation program in NETL could

[‡] https://www.energy.gov/seab/downloads/interim-report-task-force-doe-national-laboratories

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consider focused effort on carbon management and launch innovative small businesses in this field, which would then attract large corporations for partnerships.

Question 3: Some electric utilities have prioritized investment in research, development, and demonstration (RD&D) of new energy technologies. At times, this is in response to federal or state policy goals, or it indicates the willingness of utilities to participate in federal financing programs to demonstrate large-scale projects suited to their service territories and regional needs. Former Energy Secretary Ernest Moniz recently published a report outlining utility involvement in RD&D activities, and calling for more of it. There are limitations to what these utilities can invest compared to other competitive industries. Because of the vast customer bases that utilities serve, it seems to me that they are well positioned to be leaders in this space if we give them the right tools.

What federal incentives or policy changes are needed to increase the participation of electric utilities in research, development, and commercialization of energy technologies?

I fully agree with former Secretary of Energy Ernest Moniz that the utility sector should ramp up their RD&D activities in view of both future opportunities and threats. Before I outline the role of the federal government, here are some points to note:

1. Threats: As we are now witnessing in California, the utility sector needs to better understand the evolving risk landscape. Some of these are natural, such as fires and floods due to extreme weather conditions, and others are business risks (e.g., community choice aggregators; increasing discrepancy between wholesale and retail prices; stranded assets) or cyberphysical risks (e.g., Metcalf substation; Ukraine).
2. Opportunities: The electricity sector is undergoing a once-in-a-century transformation. On one hand, the grid was never designed to have large penetration (>50%) of renewables which introduce variability in generation. On the other, it was also not designed to have large fluctuations of loads, which will be introduced by fast charging of electric vehicles especially when there is deep penetration (>50%). Furthermore, we are likely to witness broader electrification of the industrial sector as well. To manage the variability and fluctuation on both supply and demand, the utility sector needs to adopt digital technologies for both planning and coordinated operation so that it maximizes the installed capacity and thereby reduces cost and increases reliability.
3. Innovation Ecosystem – Internal & External RD&D: To mitigate such risks, it is very important the utilities create and leverage an innovation ecosystem of small and large businesses as well as universities and national laboratories. But that would require that utilities create internal RD&D teams and programs that provide an impedance match with the external ecosystem. Given the large customer base, this would be very much welcome by both small and large businesses with utility forming a business channel.
4. Leveraging RD&D Consortia: To de-risk technologies before deployment, utilities can increase the engagement and leveraging non-profit organizations and consortia like the Electric Power Research Institute (EPRI) to lead demonstration projects of innovative technologies.
5. Regulatory Reform: Since many of our utilities are regulated, this would require regulatory reform as well. That is, the regulators need to understand the risks, challenges and opportunities and

become stewards of the utility sector to become the platform for both innovation and delivery of innovative solutions. This is the domain of states, not the federal government.

6. Role of the Federal Government: In 1936, Congress passed the historic Rural Electrification Act where the federal government provided low-interest loans via local electric power cooperatives to bring electricity services and an enviable quality of life to millions of Americans across our nation. We need a 21st century version to foster RD&D and innovation in the electricity ecosystem. For example, the federal government can run a competition between states to access a combination of low-interest federal loans and grants, but in exchange, the states would need a plan that would be a combination of regulatory reform that would allow new business models, combined with some state funding that would foster RD&D and create an innovation ecosystem as described above. These could be targeted to include: energy efficient homes and buildings; intelligent electric grid that integrates large amounts of intermittent renewables, storage, as well as zero-emissions nuclear and fossil energy; electrification of public transit, automobiles and rail transport for moving people and freight; low-carbon heat and electrification of our industry, etc.

Question 4: The power sector does not exist in a vacuum. If we are serious about curbing emissions we must look across sectors and take in to consideration how they affect each other. Transportation accounted for the largest portion of total U.S. greenhouse gas emissions in 2016, with the industrial sector close behind. To truly consider global, national, and regional perspectives we have to look at the big picture on this.

What opportunities do you see to reduce greenhouse gas emissions in other sectors, like transportation and industry?

I fully agree that to reduce overall greenhouse gas emissions, it is important to decarbonize all sectors of our economy. Having said that, decarbonization of the power sector should be considered a necessary enabler for decarbonizing the other sectors, but it will not be sufficient. Here is why.

1. With the cost of lithium ion batteries rapidly reducing, it is expected that by 2025, electric vehicles (EVs) will have cost and range parity with gasoline cars without subsidies. Hence, if the power sector is decarbonized it will enable decarbonizing the light-duty segment of the transportation sector. But this will need very significant investments in charging infrastructure, especially for deep penetration of EVs over the next 20 years.
2. Since it will take 20-25 years for deep EV penetration it is critical that fuel efficiency standards (CAFE standards) are kept in place and increased over time. This will be very important to reduce greenhouse gas emissions. This is particularly relevant for long-haul trucking which will be difficult to electrify using batteries cost-effectively.
3. To decarbonize long-haul trucking, it is also important to consider low-carbon high-density fuels such as hydrogen (or methanol) that could potentially use carbon-free electricity or natural gas. This requires R&D to reduce the cost of carbon-free high-density fuel production and make it competitive with diesel.
4. Industrial heat, which is generated by burning natural gas at roughly 1-2 cents/kWh (natural gas price of $3/MMBTU), is perhaps the most difficult sector to decarbonize. The DOE should consider investing in R&D to efficiently electrify industrial heat production. This could be

directly via inductive electrical heating or via low-cost production and the efficient utilization of hydrogen. The need to decarbonize industrial heat could also offer an opportunity for small modular or micro nuclear reactors to provide carbon-free heat. But any alternative approach must meet the cost target of 1-2 cents/kWh for industrial heat, which will require R&D.

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Appendix 1

ENERGY

Energy Innovation Needs New Private-Sector Push

7 FEB 11, 2016 9:15 AM EST

By Arun Majumdar & John M. Deutch & Norman R. Augustine & George P. Shultz

Two months after the end of the Paris climate summit, it seems natural to ask: What are the next steps? Do we need to do more?

Three initiatives launched around the Paris meeting are an important start. Bill Gates announced the formation of the Breakthrough Energy Coalition, composed of philanthropists who will invest in public-private partnerships to invent and scale technologies. More than 20 countries led by the U.S. unveiled "Mission Innovation" and pledged to seek to double their government research-and-development budgets over the next five years to accelerate clean-energy innovation. Ten of the world's largest oil and gas companies launched the "Oil and Gas Climate Initiative" to organize meaningful action through the sharing of best-practice information and other industry collaboration as well as to make investments in R&D and startups.

These statements indicate that both the public and private sectors recognize that we live in a carbon-constrained world and that there will be a charge on carbon emissions, imposed through regulations or market prices or a combination of both. Thus, there is an imperative for industry to explore the commercialization of new innovative low-carbon technologies.

Given the scale of the energy and climate challenges, the three initiatives are necessary but not sufficient. Why? Successful innovation must address technologies from creation to deployment.

Take, for example, advances in battery technology. A battery that costs less than $100 per kilowatt-hour with a lifetime of more than 1,000 cycles would be a game changer for offering affordable and reliable renewable electricity across the world. Today's lithium ion batteries cost three times more. We need government R&D to support fundamental

work in our universities and national laboratories and the Breakthrough Energy Coalition as a first step to developing product prototypes and systems.

Success means taking a promising technology all the way to the demonstration of commercial viability. This includes pilot demonstrations, the creation of supply chains, and the ability to reduce costs and meet regulatory compliance.

In the energy sector, this innovation journey requires on the order of $1 billion over 10 years. Currently, there is no private-sector mechanism to address this challenge, and promising new technologies will likely die.

We propose a new approach to address this gap: Create a number of Energy Innovation Entities to bring key technologies to commercial use; each Energy Innovation Entity would be supported by roughly 10 companies, each committing about $10 million a year for 10 years -- a "10-10-10" mechanism.

No single technology will address the energy and climate challenge. There are more like 10 such technologies that deserve to be considered for creating individual entities, all of which could offer the private sector the needed competitive advantage. Without them, businesses face the risk of being blindsided if they do nothing.

How should these entities be governed? The 10 sponsoring companies would select a board that would pick a chief executive officer to assemble and lead a team to design and carry out the 10-year program.

The different entities would likely choose different development paths, such as: creating a new technical facility and work force; forming partnerships with universities and small businesses; establishing R&D laboratories and companies for key subsystems; or setting up a joint venture with members of an international value chain that combines the people and facilities of the sponsors.

Each entity would own all the resulting intellectual property and know-how from its work, and decide to pursue deployment on an individual basis, in a partnership or through a new or existing enterprise. Undoubtedly, during the 10 years, some entities would not meet expected technical milestones, costs and schedules; others might meet goals early. Accordingly, at any point, a majority of the sponsors should have the right to terminate the project.

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In the U.S., the only entity that can potentially afford a $1 billion budget for 10 years to demonstrate commercial viability for a specific new technology is the federal government. But it is hard to overstate the advantages that a private-sector innovation project has over one supported by the U.S. Department of Energy for late-stage demonstration programs.

Federally sponsored demonstration projects involve many specific rules and regulations that impose extra cost and time requirements. There are restrictions on procurement practices, requirements for cost and performance reports, significant uncertainties on the timing and amount of contract payments, let alone questions about consistent Congressional backing.

Not surprisingly, the DOE's record in downstream technology demonstration has been mixed. The various reasons for this include: changing priorities; shifting markets; congressional influence; underfunding of projects; and lack of professionals with adequate market, finance and management experience. Despite some successes, there have been many disappointments, including the Clinch River Breeder Reactor Project, the Synthetic Fuels Corporation and FutureGen.

Indeed the difference in how federally supported and private-sector technical development programs are run is so great that private investors and their banks find it difficult to evaluate confidently in the case of the government if required investment criteria have been demonstrated. A private-sector innovation project, if successful, is more likely to result in deployment of technology than a federal one.

We do not suggest that the "10-10-10" private-sector mechanism replace action by individual companies or government technology creation programs such as ARPA-E. Governments also have a role in areas where the private sector will not venture such as carbon dioxide sequestration, nuclear waste disposal and traditional approaches to fusion energy.

Is it wishful thinking that the energy sector will stand up to such a challenge? In the past, industry consortiums have come together, in some cases with government encouragement and support, to address a common technical challenge. Examples include the Gas Research Institute, the Electric Power Research Institute, the Microelectronics and Computer Technology Corporation, Commercial Satellite Corporation and Sematech.

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Indeed, federal, state and local governments should support the private-sector effort to create Energy Innovation Entities, since they will lead to local economic growth and jobs. The Breakthrough Energy Coalition that intends to invest in startup ventures should also help create Entities that will help the transition of early-stage technologies into commercial products at scale.

The 10-10-10 mechanism offers a powerful innovation pathway that allows groups of companies to share the risks, costs and rewards without onerous government involvement and, potentially, to greatly broaden the scope and pace of energy innovation in the U.S. and the world. This would be a strategic advantage in a competitive and rapidly changing carbon-constrained global economy.

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Question from Chairman Lisa Murkowski

Question: Please elaborate on your position that a competitive market for zero-carbon resources may be the lowest-cost option to achieve ambitious carbon reduction goals.

- How would a competitive market for zero-carbon resources work with our current electricity markets?

Answer:

We propose that a market-based auction is the best way to deliver clean energy attributes to consumers at the lowest possible price. In a competitive environment, consumers benefit both because supply costs are minimized, while private sector innovation and investment are maximized.

Further, a competitive market approach to meeting carbon targets is particularly important, because the current strategy of subsidizing certain sources of electric generation without a market nexus is costly to consumers and destructive to our current organized wholesale electricity markets. The organized wholesale markets provide billions of dollars in savings annually to consumers and if we do not act to harmonize state and federal policies, we risk losing those benefits.[1]

Key to this harmonization process is building a clean energy market that builds on the price signals being sent by today's organized markets. For example, developers in our clean energy market would assume a baseline of revenues that they expect to earn in today's competitive wholesale market environment. The developer would then identify the additional revenues that they need to make the project viable. This additional needed revenue would form the basis of the developer's offers to sell clean energy attributes. If the clearing price of the clean energy attributes exceed the amount of revenues the developer needs, the project would get built and the developer would make a profit. If the clearing price is below the level needed, the developer would likely not clear its project in the clean energy market and elect not to build the project. Society is better off because lower cost projects would be selected and competitive markets would have procured the lowest cost carbon-free power.

But of course, a competitive clean energy market, such as the one I recommend, only works if we have a healthy market price signal being sent by the underlying wholesale market with the fewest possible subsidies contaminating the outcome. Thus, it is critically important that the Federal Energy Regulatory Commission continue to ensure that its markets send appropriate price signals and that its work to expeditiously modernize its markets, particularly as the underlying mix of resources on the system changes.

[1] PJM has conducted several studies evaluating consumer savings. *See, e.g.*, https://www.pjm.com/-/media/library/reports-notices/special-reports/2019/the-benefits-of-the-pjm-transmission-system.ashx?la=en and https://www.pjm.com/-/media/library/reports-notices/special-reports/20160505-resource-investment-in-competitive-markets-paper.ashx?la=en.

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Questions from Ranking Member Joe Manchin III

Question 1: As the number one funder of clean energy R&D, the Department of Energy (DOE) plays a critical role in the innovation process, from early-stage research all the way through testing and deployment. A number of changes to improve DOE have been made over the years by Congress or the Executive Branch. Former Energy Secretary Ernest Moniz made the case before the Committee that DOE's organization by fuel-type is stifling innovation. I have requested that the Government Accountability Office review the DOE's R&D efforts to get a better understanding of what's working, and where there is room for improvement in DOE's efforts to commercialize much-needed technologies.

What organizational barriers can you identify at DOE?

What ideas do you have on what we can do, structurally, to get technologies successfully through the valley of death?

Answer:

The Department of Energy's research divisions are critically important to the development of the next generation of energy technology, and many of NRG's most innovative power plant investments would not have been possible without DOE support.

One organizational barrier within the DOE is the fact that promoting effective energy markets is not seen as part of DOE's core mission. This is particularly true for DOE projects focused on preserving existing power plant technologies that may no longer be competitive in today's energy markets without regard for making those technologies more innovative or compatible with the modern electric grid. For example, several recent DOE efforts have focused on creating out-of-market support mechanisms for specific generating technologies that would hamstring our Nation's energy markets.[2] These efforts to prop up existing generation technologies stands in stark contrast to the very successful efforts at the DOE to drive discovery and innovation for new discoveries and advances in fundamental energy research.

I agree that innovation requires that we, as a society, be able to take new energy technologies from drawing board to commercial operation in an expeditious manner. DOE funding is critical to supporting new technologies through the equivalent of venture capital's death valley's curve. Initiatives such as the Advanced Research Projects Agency–Energy ("ARPA-E") has a proven track record of success in developing new ideas into commercially-ready technologies. As a case study of effective government support, I would point to NRG's innovative Petra Nova carbon capture and sequestration project. I would commend the forthcoming testimony of my colleague, Ms. Judith Lagano, on the specifics of what has worked and what can be improved.

[2] *See, e.g.*, Grid Reliability and Resilience Pricing, Docket No. RM18-1-000.

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The key to effective competitive markets is to ensure that DOE support is limited to technologies and ideas that have not yet reached commercialization. Once a technology has been successfully commercialized, the commercial sector should take over the deployment of the new technology using private, shareholder dollars. One thing that the DOE should not do is use tax dollars to support technologies that competitive markets have rendered uneconomic. Supporting technologies in economic decline only undermines the efforts of innovators and the private market to bring new technologies into the commercial marketplace.

Question 2: Some electric utilities have prioritized investment in research, development, and demonstration (RD&D) of new energy technologies. At times, this is in response to federal or state policy goals, or it indicates the willingness of utilities to participate in federal financing programs to demonstrate large-scale projects suited to their service territories and regional needs. Former Energy Secretary Ernest Moniz recently published a report outlining utility involvement in RD&D activities, and calling for more of it. There are limitations to what these utilities can invest compared to other competitive industries. Because of the vast customer bases that utilities serve, it seems to me that they are well positioned to be leaders in this space if we give them the right tools.

What federal incentives or policy changes are needed to increase the participation of electric utilities in research, development, and commercialization of energy technologies?

Answer: NRG generally supports relying on the competitive market to drive investment in new commercially-available technologies, particularly in areas of the country that have competitive retail or wholesale markets. One of the best ways to drive innovation and choice in the energy sector is to establish technology-inclusive products, and then rely on the market to purchase more of those attributes.

There is a definitive role for government in making this happen.

First, NRG suggests that the government policies promote the ability of retail customers to shop for electricity without the unnecessary restrictions that exist in many parts of the country today. Allowing customers to purchase power that aligns with their societal views and values delivers real change to the electric grid without government mandates or additional investment of government funds. Government restrictions on the ability of customers to shop harms innovation and removing those restrictions is an important first step to jumpstarting the American energy economy.

Second, government should re-affirm its view that competitive markets are the primary means of driving investment in the energy space. Competition and markets have been the hallmark of the American economy since its founding, and we should continue to insist on a robust role for market-based solutions. Reliance on competition ensures that private investment dollars enter the electricity sector, while minimizing the danger that utility investment of ratepayer funds replaces that private investment.

Third, in order for market-based solutions to meet society's energy aspirations, government needs to be able to set its policy priorities. These priorities could be set at the state or federal level and could address

a variety of potential policy goals, including carbon content, reliability, or fuel security, to name a few. Once the goals are established, the best way of achieving them is to utilize a competitive market structure that procures the necessary attributes at the least possible cost to consumers.

Question 3: The power sector does not exist in a vacuum. If we are serious about curbing emissions we must look across sectors and take in to consideration how they affect each other. Transportation accounted for the largest portion of total U.S. greenhouse gas emissions in 2016, with the industrial sector close behind. To truly consider global, national, and regional perspectives we have to look at the big picture on this.

What opportunities do you see to reduce greenhouse gas emissions in other sectors, like transportation and industry?

Answer: There is no question that an *economy-wide* price on carbon is the best possible way of introducing competition across the transportation, building, and energy sectors. While it is possible to reduce electric sector emissions lower, doing so is only one piece of a much larger emissions pie.

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Questions for the Record Submitted to Ms. Sarah Ladislaw

Questions from Chairman Lisa Murkowski

Questions: I recently reintroduced the Nuclear Energy Leadership Act with the goal of keeping the U.S. a world leader in the development of advanced nuclear reactors. We currently have 17 Senate cosponsors, including many members of Committee on Energy and Natural Resources.

- **Why is the U.S. no longer a global leader in nuclear energy?**

The United States ceased to be a global leader in nuclear energy for three major reasons. First, U.S. nuclear power generation projects have become economically unattractive, reducing the domestic construction demand that could have helped to sustain the U.S. industry's ability to cap or reduce the cost of reactor production/project construction as well as maintain skilled workforce. A combination of domestic factors, including power market deregulation which fails to adequately compensate for zero-carbon nature of nuclear power generation and the rising cost of safety and environmental safeguards compliance have rendered nuclear power projects economically unattractive. More recently, the availability of cheap natural gas for electricity generation has exacerbated the economics of nuclear power generation. Second, Russia began outcompeting U.S. with its creative deals and flexible financing terms while U.S. vendors became more focused on licensing reactor designs to other countries than aggressively securing contracts for new builds. Nuclear export deals by non-market economies include in-house fuel cycle, ownership of a reactor abroad, spent fuel take-back, as well as financing terms that are outside the bounds of OECD export credit regulations, and they are extremely difficult for a U.S. vendor to replicate. (China has a very limited track-record in nuclear exports but is an aspiring supplier.) Such terms by non-OECD suppliers meet many of the needs of newcomer markets that lack a strong financial backbone, or nuclear regulatory system. Third, competitive nuclear energy innovation requires a stable, long-term funding as well as clear regulatory environment, both of which have been largely absent in the United States. In contrast, nuclear energy is a key focus of innovation strategy as well as export industry of Russia and China, and thus has enjoyed a high level of budgetary and political support.

- **Please detail your perspective on the importance of maintaining U.S. leadership in nuclear energy, not only for national security, but also for reducing carbon emissions.**

U.S. leadership in nuclear energy has multiple benefits. First, waning U.S. leadership could diminish U.S. effectiveness or relevance in setting priorities and approaches under a global nonproliferation regime, which may come to be led by countries with more advanced scientific and technological expertise, but less committed to nonproliferation norms and principles. Second, losing a leadership role and being chronically outcompeted could weaken both the supply chain for nuclear reactor equipment and components as well as the caliber of nuclear scientists and engineers that are needed to maintain the U.S. nuclear defense apparatus (although it is not clear that these national security goals would go unmet absent a robust commercial nuclear industry). Third, nuclear energy is a technologically proven way of generating electricity that emits virtually no carbon or greenhouse gases while providing much higher energy density than most other power sources available today. Nuclear energy provides more than 55 percent of carbon-free electricity in the United States, avoiding 528 million metric tons of CO2 emissions

in 2018—more than twice the level of carbon emissions avoided by hydropower, which was the next carbon-free source of electricity last year. The decarbonization of power sector is one key foundation for the world's chance of avoiding the worst impacts of climate change as discussed in the 2018 report by the Intergovernmental Panel on Climate Change (IPCC). The U.S. ability to maintain its existing fleet of nuclear power plants is essential for its effort to minimize its impact on the global carbon budget. Moreover, the United States has decades of experiences in safe operation of its nuclear power plants. Continued U.S. leadership in upholding and advancing operational safety as well as nonproliferation are essential if nuclear energy is to preserve a material share in the global power supply mix, and assist in efforts to reduce carbon emissions.

Questions from Ranking Member Joe Manchin III

Question 1: As the number one funder of clean energy R&D, the Department of Energy (DOE) plays a critical role in the innovation process, from early-stage research all the way to testing and deployment. A number of changes to improve DOE have been made over the years by Congress or the Executive Branch. Former Energy Secretary Ernest Moniz made the case before the Committee that DOE's organization by fuel-type is stifling innovation. I have requested that the Government Accountability Office review the DOE's R&D efforts to get a better understanding of what's working, and where there is room for improvement in DOE's efforts to commercialize much-needed technologies.

What organizational barriers can you identify at DOE?

Given its complex organizational nature of DOE and all the entities involved in the RDD&D mission, the budgeting, decisionmaking, and performance evaluation process at DOE has often been subject to review. In our recent report on *The Changing Role of Energy in the U.S.* Economy, we discuss how progress in energy innovation is very difficult to quantify in ways that capture the true value of the activities. Both of the last two administrations undertook organizational reform efforts largely designed to tackle the same categories of critiques about efficiency and effectiveness that are often levied at DOE. In Secretary Moniz's testimony and accompanying report *Advancing the Landscape for Clean Energy Innovation,* he calls for the Department of Energy's innovation efforts "along a new applications-based structure that puts energy production, distribution, and applications in logical groupings that enable comparative analyses and prioritization among technologies serving similar needs." This is in line with contemporary analysis of the evolution of the energy sector towards a much more integrated and systems oriented approach to thinking about the modern day challenges of delivering energy services. It also reflects the thinking of the private sector which is taking a much more integrated approach to the convergence of different energy systems (i.e. through greater electrification). Whether through organizational changes or a cross-cutting review process, thinking about DOE's priorities from this vantage point could provide benefits.

What ideas do you have on what we can do, structurally, to get technologies successfully through the valley of death?

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As *Advancing the Landscape for Clean Energy Innovation* also notes, there are several valleys of death in the innovation cycle, each requiring a consolidated strategy to overcome the barriers to the next stage in the innovation cycle. I find compelling two particular ideas designed to help with specific aspects of this problem. The first is the prioritization of particular challenges that pull a technology through one stage of the RDD&D process to another. This "challenge" construct can be designed in a way to move technologies from one stage of development to another by targeting a specific aspect of performance. The SunShot Initiative is one good example. The second idea is to create an institution dedicated to demonstration projects as suggested by David Hart in his 2017 publication *Across the "Second Valley of Death": Designing Successful Energy Demonstration Projects*. Demonstration projects are an important part of moving technologies from the late-stage R&D phase of development and into the marketplace. Hart's paper recommends the DOE maintain robust and diverse portfolio of demonstration projects, prioritize information sharing and private sector engagement, and be willing the terminate non-viable projects. Beyond these recommendations for improving DOE performance it is critical to have more "market pull" incentives in place to drive demand for these new technologies. The scale of energy systems level change required to pursue deep decarbonization of a time-relevant magnitude simply will not happen without more robust policies and regulations driving market behavior.

<u>Question 2</u>: Some electric utilities have prioritized investment in research, development, and demonstration (RD&D) of new energy technologies. At times, this is in response to federal or state policy goals, or it indicates the willingness of utilities to participate in federal financing programs to demonstrate large-scale projects suited to their service territories and regional needs. Former Energy Secretary Ernest Moniz recently published a report outlining utility involvement in RD&D activities, and calling for more of it. There are limitations to what these utilities can invest compared to other competitive industries. Because of the vast customer bases that utilities serve, it seems to me that they are well positioned to be leaders in this space if we give them the right tools.

What federal incentives or policy changes are needed to increase the participation of electric utilities in research, development, and commercialization of energy technologies?

Utilities can play an important role in bridging the gap between R&D and deployment and commercialization of new energy technologies. Some of the recommendations in the previous two studies mentioned can help them play a more effective role in the demonstration process. I have not done specific work on the incentives for utilities to invest more in R&D and therefore will only offer ongoing exploration of the role of the utility business model and process of cost-recovery that oftentimes impedes utilities from playing a bigger role and the lack of clear incentives around issues like grid modernization or the future of the electric power system. Thus far, industry led consortiums have played an important role in the utility approach to engaging with R&D.

<u>Question 3</u>: The power sector does not exist in a vacuum. If we are serious about curbing emissions we must look across sectors and take in to consideration how they affect each other. Transportation accounted for the largest portion of total U.S. greenhouse gas emissions in 2016, with the industrial

sector close behind. To truly consider global, national, and regional perspectives we have to look at the big picture on this.

What opportunities do you see to reduce greenhouse gas emissions in other sectors, like transportation and industry?

The latest UN Intergovernmental Panel on Climate Change report (and many before it) point out that there are many technology and policy options available to reduce emissions along one of the many recommended emissions reductions pathways. In the transportation sector (the largest source of U.S. greenhouse gas emissions) options include improving vehicle efficiency, promoting new and more efficient modes of transportation (public transport, ride sharing and autonomous vehicles), and fuel switching for lower emitting sources of energy like biofuels, natural gas, hydrogen and electricity. All of these pathways and options have challenges, but all can be advanced through sound public policy incentives and regulatory structures and increased R&D to further improve the performance and affordability of these alterative options. With regard to industrial emissions, responsible for approximately 20 percent of U.S. greenhouse gas emissions, and emissions associated with electricity usage, options include energy efficiency, combined head and power, fuel switching, and carbon capture and sequestration. Just as in the transportation sector, a number of policy and regulatory changes as well as investment in industrial emissions oriented RD&D would assist in advancing these solutions.

Question 4: Advanced nuclear reactors have enjoyed rare bipartisan support over the last few years, with two important bills enacted just last Congress. Some U.S.-based companies are eager to bring advanced nuclear reactors – technologies with unique capabilities that could play an important role in the global economy – to market. For example, high temperature nuclear is critical to enabling industrial processes that require temperatures above 300 degrees Celsius.

Are you aware of other non-carbon emitting technologies that can provide the high temperatures – that is, over 300 degrees Celsius - needed for process heat applications other than advanced nuclear?

Nuclear power is one technology that can produce high temperature process heat in steady-state and likely with high reliability as advanced reactors are deployed and achieve the capacity factors achieved today. Other technologies that could provide high temperatures (over 300 degrees C) without emitting carbon could include the burning of non-carbon emitting gases, such as the burning of hydrogen and oxygen-hydrogen gas mixtures. Thus, technologies that could lead to the non-carbon emitting production of hydrogen (which could include nuclear or renewable energy sources) could provide non-carbon emitting process heat at high temperature.

Can you discuss the importance of maintaining the U.S. leadership in nuclear technology, the need to access international markets, and maintaining the current fleet and deploying new nuclear plants to curb emissions?

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Nuclear energy provides about 20 percent of the current U.S. electricity needs, and it accounts for 55 percent of the non-carbon emitting electricity generation in the country. It produces electricity with a high capacity factor; it is available to produce about 90 percent of the time, 24 hours per day, 7 days per week. The United States also uses nuclear power for propulsion by the U.S. Navy in both submarines and aircraft carriers, as well as for production of radioisotopes used in industry and the medical areas. Finally, the U.S. maintains its stockpile of nuclear weapons, which does rely on an in-depth understanding of nuclear technology. In the broadest sense, the U.S. must continue to maintain a leadership position in nuclear technology to continue to support all of the current mission needs that rely on nuclear. For commercial nuclear, it would be beneficial for the U.S. to maintain a leadership position in nuclear technology to ensure that we can deploy nuclear reactors in the U.S. to reduce our carbon emissions from electricity generation and provide additional electricity generation for transportation electrification needs. Given that most other countries are still pursuing the commitments made as part of the Paris Agreement and noting that nuclear is an option being pursued by several countries for clean electricity generation, it would be valuable for the U.S. companies to have and maintain access to international markets to serve as customers and also provide the impetus to build capacity in the U.S. to allow for meeting the U.S. demands for nuclear energy if that ramps up in the coming decades.

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Questions for the Record Submitted to the Honorable David Sandalow

Questions from Chairman Lisa Murkowski

Questions: You are clear in your belief that improving the energy efficiency of buildings is an opportunity to reduce emissions. In your written testimony, you point out that buildings today consume 40 percent of our primary energy and 75 percent of our electricity.

- How can we account for the unique Arctic challenges when we are determining the best way to capture the energy efficiency gains and emissions reductions available to us in the building sector?

  Energy efficiency gains in the building sector are especially valuable in the Artic, due to cold temperatures and high fuel costs. Building designs should reflect this, incorporating best practices from around the region and innovations in the sector. Regular monitoring of building operations is important as well, to ensure that energy efficiency opportunities are captured on an ongoing basis.

- Are there opportunities for the federal government to make better use of local entities like the Cold Climate Housing Research Center, who already have the necessary local knowledge, cultural expertise, and relationships to be effective, in Fairbanks, Alaska?

  The Cold Climate Housing Research Center has a track record of success in promoting energy efficient buildings in Alaska. Federal support for Center programs can have significant benefits. Federal funding to help cover core costs for the Center should be considered.

Questions from Ranking Member Joe Manchin III

Question 1: As the number one funder of clean energy R&D, the Department of Energy (DOE) plays a critical role in the innovation process, from early-stage research all the way to testing and deployment. A number of changes to improve DOE have been made over the years by Congress or the Executive Branch. Former Energy Secretary Ernest Moniz made the case before the Committee that DOE's organization by fuel-type is stifling innovation. I have requested that the Government Accountability Office review the DOE's R&D efforts to get a better understanding of what's working, and where there is room for improvement in DOE's efforts to commercialize much-needed technologies.

What organizational barriers can you identify at DOE?

Multi-year planning is important for energy innovation, in part because R&D often requires years to reach fruition. The annual appropriations process creates challenges for DOE's energy innovation mission. Important steps have been taken to address these challenge in recent years, including quadrennial reviews and budget requests with proposed five-year funding levels. However more is needed. Congress should work closely with DOE to explore new tools, including multiyear appropriations and program planning.

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DOE's structure is not optimal in several respects. For example, the placement of energy efficiency and renewable energy functions in a single office risks minimizing attention to the efficiency of fossil energy technologies – an important topic. However reorganizations are often time-consuming and costly. Reorganization of units within the federal government can take years and divert time and attention from an agency's core mission. Such reorganizations can be useful, but before embarking on any reorganization Department leadership should do a rigorous analysis of likely costs and benefits. This should include an estimate of person-years likely to be required to implement the reorganization and specific benefits anticipated.

What ideas do you have on what we can do, structurally, to get technologies successfully through the valley of death?

Reducing risk for deployment of innovative technologies is especially important. DOE's Loan Program Office provides an important model. LPO's success in helping launch the utility-scale solar industry in the US is an example of the role government can play in cutting emissions and creating jobs. To help prevent politicization of this important program, future authorization legislation could explicitly recognize that energy technology is by its nature risky and that some companies funded under the LPO will fail (just as some companies funded by private lenders fail).

Question 2: Some electric utilities have prioritized investment in research, development, and demonstration (RD&D) of new energy technologies. At times, this is in response to federal or state policy goals, or it indicates the willingness of utilities to participate in federal financing programs to demonstrate large-scale projects suited to their service territories and regional needs. Former Energy Secretary Ernest Moniz recently published a report outlining utility involvement in RD&D activities, and calling for more of it. There are limitations to what these utilities can invest compared to other competitive industries. Because of the vast customer bases that utilities serve, it seems to me that they are well positioned to be leaders in this space if we give them the right tools.

What federal incentives or policy changes are needed to increase the participation of electric utilities in research, development, and commercialization of energy technologies?

The structure of the electric utility industry creates several barriers to greater investment in energy innovation. In part as a result, the federal government has an especially important role in promoting innovation in the electric sector. Federal funding for R&D is essential. Tax credits have played an important role in helping commercialize clean energy technologies. Federal support for industry innovation programs including those at the Electric Power Research Institute can pay significant dividends.

Question 3: The power sector does not exist in a vacuum. If we are serious about curbing emissions we must look across sectors and take in to consideration how they affect each other. Transportation accounted for the largest portion of total U.S. greenhouse gas emissions in 2016, with the industrial sector close behind. To truly consider global, national, and regional perspectives we have to look at the big picture on this.

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What opportunities do you see to reduce greenhouse gas emissions in other sectors, like transportation and industry?

Fuel efficiency standards are a proven tool for saving energy, cutting costs and reducing emissions in the transport sector. Incentives for deployment of electric vehicles are important as well. Lifting the per-manufacturer cap on the electric vehicle tax credit and restoring the tax credit for electric vehicle charging equipment would help speed the transition to electric vehicles. Continued support for energy storage R&D is important as well.

Industrial emissions are an especially important topic. Federal procurement statutes should be amended to specifically encourage purchase of products made with low-carbon processes. The Industrial Heat Decarbonization Roadmap, which I recently released along with several co-authors, provides considerable additional detail on this topic. The Roadmap is available at https://www.icef-forum.org/pdf2019/roadmap/ICEF_Industrial_201910.pdf

U.S. Senate Committee on Energy and Natural Resources
April 11, 2019 Hearing: ***Opportunities for Energy Innovation and Other Potential Solutions to Help Address Global Climate Change***
Questions for the Record Submitted to Mr. Robert Bryce

Questions from Chairman Lisa Murkowski

Question 1: In your view, what are some of the problems associated with attempting to implement a carbon tax, especially as it pertains to lower-income families?

Robert Bryce's reply:
Making energy more expensive would impact low-income families more than wealthier individuals because they would be forced to spend a larger share of their income on things like gasoline and electricity. This would be particularly true for low-income families who live in rural areas and must commute long distances to get to their job sites. For more on this, please see my attached article, "The Three Major Problems with a Carbon Tax," which was published on February 4, 2019 in *National Review*.

Question 2: I recently reintroduced the Nuclear Energy Leadership Act with the goal of keeping the U.S. a world leader in the development of advanced nuclear reactors. We currently have 17 Senate cosponsors, including many members of Committee on Energy and Natural Resources.

- Why is the U.S. no longer a global leader in nuclear energy?

Robert Bryce's reply:
Numerous factors have contributed to the slow decline of the US nuclear sector. Chief among them: the hyper-diffused ownership structure of the American electric grid. Some 3,300 different electricity providers are connected to the domestic grid, including more than 2,000 publicly owned utilities and about 900 electric cooperatives. The diffused nature of this ownership model makes it difficult to muster the political and economic support needed to make the multi-billion-dollar commitments needed to bring new nuclear capacity online. This diffused ownership has prevented the industry from getting long-term, bipartisan support in Congress for the development and deployment of new nuclear technologies.

In addition, low-cost natural gas and subsidized renewables have driven down the price of electricity at the wholesale level. Those factors have made it harder for nuclear reactors to be profitable.

Further, it must be stated that America's biggest environmental groups has spent decades demonizing nuclear energy. For instance, the Sierra Club, America's largest environment group, has been an ardent opponent of nuclear energy since 1974. In 2016, Michael Brune, the executive director of the Sierra Club reaffirmed the club's position, saying it "remains in firm opposition to dangerous nuclear power." Other influential environmental groups like the Natural Resources Defense Council, Greenpeace, and 350.org, are also opposed to nuclear energy. Rather than fight those groups on permitting and in the court of public opinion, many electric utilities have decided to simply abandon nuclear energy.

- Please detail your perspective on the importance of maintaining U.S. leadership in nuclear energy, not only for national security, but also for reducing carbon emissions.

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Robert Bryce's reply:
As I explained in my written testimony, there is no credible pathway toward large-scale decarbonization that does not include large-scale deployment of nuclear energy. The U.S. should invest in nuclear energy to assure its technological leadership in that arena. The U.S. has been leading the world in the development and deployment of nuclear energy since the 1950s. It still produces twice as much electricity from fission as France. But a look around the world shows that state-owned companies like Russia's Rosatom, South Korea's KEPCO, and China's China National Nuclear Corporation are the only ones who are deploying new reactors at any kind of scale.

It will be difficult (or perhaps impossible) for Congress to create a similar state-backed company. But Congress can facilitate the private development of new, safer reactors in the U.S. by allowing private companies to partner with the nuclear-focused national laboratories. Several U.S. companies are developing new nuclear technologies. They need federal support so that the U.S. can continue to be a leader in nuclear energy. Leadership will be needed if the world is to have any hope of making sustained reductions in carbon dioxide emissions. That point was made clear in an April 2019 paper by three researchers from the University of Chicago. In their report, which assessed the high cost of renewable-energy mandates, the authors concluded that "policies that substantially increase the price of electricity tend to have a regressive impact that hits low-income consumers hardest, and therefore may be especially unattractive in developing countries that account for a large and growing share of global emissions. The most effective climate policy in technologically advanced and innovative nations such as the United States will reduce emissions domestically, but also involves developing low-carbon energy systems that are cost-effective enough to promote adoption in the rest of the world."[i]

The U.S. should be developing the low-carbon energy technologies that can be adopted by other countries. And the only low-carbon energy technology that can provide the vast scale of new electricity-generation capacity needed to address the greenhouse-gas-emission challenge is nuclear power.

Question from Ranking Member Joe Manchin III

Question: Some electric utilities have prioritized investment in research, development, and demonstration (RD&D) of new energy technologies. At times, this is in response to federal or state policy goals, or it indicates the willingness of utilities to participate in federal financing programs to demonstrate large-scale projects suited to their service territories and regional needs. Former Energy Secretary Ernest Moniz recently published a report outlining utility involvement in RD&D activities, and calling for more of it. There are limitations to what these utilities can invest compared to other competitive industries. Because of the vast customer bases that utilities serve, it seems to me that they are well positioned to be leaders in this space if we give them the right tools.

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Robert Bryce's reply:
There is no simple answer to this question. Like any other commercial enterprise, utilities adopt technologies when they make sense from a financial and practical standpoint. I will reiterate what I stated above regarding the diffused ownership in the U.S. electric grid. The vast disparity in the size of electric utilities in this country make it extraordinarily difficult to design an incentive or policy that will appeal to all of them. One possible solution might be to create a research consortium that is backed by the federal government and the utilities. The electricity providers would contribute to the consortium based on their revenues, or the number of customers they serve. The consortium could then fund research and development of energy technologies that could be utilized by all of the members who contribute to the project.

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[i] University of Chicago, Michael Greenstone, Richard McDowell, and Ishan Nath, "Do Renewable Portfolio Standards Deliver?" April 2019, https://bfi.uchicago.edu/wp-content/uploads/BFIEPIC_WP_201962_v3.pdf, 2.

ENERGY & ENVIRONMENT

The Three Major Problems with a Carbon Tax

By **ROBERT BRYCE** | February 4, 2019 6:30 AM

(Pixabay)

It faces both political and practical obstacles.

When it comes to energy policy, Washington has one resource that appears infinitely renewable: carbon-tax proposals.

Al Gore proposed a carbon tax back in 1992.

The Clinton administration tried, and failed, to impose a “Btu” tax on all forms of energy. The latest iteration of the carbon tax is the “carbon dividend” plan, which was endorsed last month by a group of Nobel-winning economists, chairs of the Federal Reserve, and two former Treasury secretaries.

Proponents claim that a carbon tax would be the most cost-effective way to cut carbon-dioxide emissions. But the carbon tax keeps running aground. There are three big problems with the concept: It would disproportionately hurt low-income consumers, it would inevitably be watered down by special interests, and it would have to be imposed on our trading partners.

The regressive effects are well known. Even if, as many proponents suggest, the proceeds of the tax were paid out to consumers on a quarterly basis rather than being used to fund the government, having to wait months to recover the extra money they’ve spent could cause financial stress for poor and working-class families.

A 2012 study by scholars from the Brookings Institution and the American Enterprise Institute found that the carbon-tax burden

"would comprise 3.5 percent of the income of the poorest decile of households and only 0.6 percent of the income of the highest decile." For low-income workers, particularly those living paycheck to paycheck, such a tax — which would mean higher prices for nearly everything — would impose a major burden. Higher energy prices would be particularly burdensome, and the payments less likely to fully cover the costs, for workers and tradesmen who live in rural areas and must drive long distances to get to and from their job sites.

Second, a carbon tax would be targeted by armies of lobbyists, with some aiming to kill it and others aiming to get a dispensation. In 1993, the *Washington Post* reported that the Clinton administration was abandoning the Btu tax because it had underestimated "the opposition the tax would face from manufacturers, farmers and the energy industry." Last November, voters in Washington State defeated a carbon-tax proposal known as Initiative 1631 by a wide margin. That tax would have exempted aviation and maritime fuel, as well as "energy intensive, trade-dependent" businesses such as steel plants, aluminum

producers, and pulp and paper mills.

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The stickiest problem with the carbon tax is the problem of "border carbon adjustments," which is another name for the tariffs that would be imposed on imported goods and services. Such tariffs will be needed, supporters say, to prevent "carbon leakage" (i.e., carbon-intensive manufacturing moving overseas) and "enhance the competitiveness of American firms that are more energy-efficient than their global competitors." That border adjustment would require calculating the greenhouse-gas footprint of nearly every single thing we import. Imagine what it might mean for a big manufacturer like Boeing, which produces airplanes with parts

that are manufactured and imported from multiple countries. Some of those parts are themselves made from parts and commodities imported from still other countries. Keeping track of all of those carbon flows, and avoiding constant disputes over the accuracy of the data, will be an accounting nightmare.

In addition to determining the right level of tariff, a carbon tax must overcome the "free-rider" problem. William Nordhaus, an economics professor at Yale University who won the Nobel Prize in economics last year for his work on climate-change policy, is a long-time advocate for a carbon tax. Nordhaus has underscored the "importance of near-universal participation in programs to reduce greenhouse gases." In 2007, he estimated that if only half of the world's countries agreed to participate in a carbon-tax effort, there would be an "abatement cost penalty of 250 percent." In other words, the countries that have imposed the carbon tax will have to more than double their carbon-tax rates in order to compensate for the free-riding countries.

Moreover, rich and poor countries alike have consistently prioritized economic growth

over substantive action on climate change. University of Colorado professor and author Roger Pielke Jr. has dubbed this the Iron Law of Climate Policy: “When policies on emissions reductions collide with policies focused on economic growth, economic growth will win out every time.” It will be especially difficult for the U.S. to get poorer countries to jump on the carbon-tax bandwagon, seeing as the average American uses five times as much electricity as the average Brazilian, ten times as much as the average Iraqi, and 16 times as much as the average Indian.

The history of international efforts to ban land mines shows how difficult it will be to impose a worldwide carbon tax. Land mines are ghastly weapons that seldom hit their intended targets. Nearly 90 percent of the people who are killed or maimed by them are civilians. All around the world, large swaths of usable land have been declared off limits to farming and human use owing to the danger of abandoned, unexploded land mines.

The effort to ban land mines has garnered widespread support. According to the International Campaign to Ban Land Mines,

164 countries have signed the Mine Ban Treaty, which was first adopted in 1997, the same year that the Kyoto Protocol was signed. But just as the Kyoto Protocol hasn't had much success in limiting greenhouse-gas emissions, 32 countries still haven't signed the mine-ban treaty, including the United States, China, India, and Russia. Thus, despite universal agreement on the awfulness of land mines, and decades of concerted effort, there is still no worldwide agreement to ban them.

If we can't get an agreement to ban land mines, how will we ever get an enforceable international agreement to tax coal, oil, and natural gas, which together currently provide 85 percent of the world's energy?

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Proponents claim carbon taxes are essential in the fight against climate change. That may be true. But my guess is that we will see a universal agreement to ban land mines before we see a substantial levy imposed on the fuels that drive the global economy.

ROBERT BRYCE *is a senior fellow at the Manhattan Institute and the producer of the forthcoming documentary* Juice: How Electricity Explains the World.
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