S. HRG. 116–289

THE ELECTRICITY SECTOR IN A CHANGING CLIMATE

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED SIXTEENTH CONGRESS

FIRST SESSION

MARCH 5, 2019

Printed for the use of the
Committee on Energy and Natural Resources

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

U.S. GOVERNMENT PUBLISHING OFFICE
35–558 WASHINGTON : 2020

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THE ELECTRICITY SECTOR IN A CHANGING CLIMATE

TUESDAY, MARCH 5, 2019

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

The Committee met, pursuant to notice, at 10:05 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.

Over the past couple weeks here, we have had hearings that looked at the energy markets of today, what could be the breakthrough energy technologies of tomorrow, and then worldwide forecasts from the International Energy Agency, IEA. In each of these hearings we have heard about the effect that climate change is having on decisions within the electricity sector. Today, we are here to consider those trends in greater detail.

Our nation's energy mix has changed significantly over the past decade, largely driven by the shale revolution and the low cost of natural gas, but also federal and state policies that have boosted low or zero emission energy technologies.

Now we all know that the electricity sector is just one piece of the puzzle when it comes to climate change, but also, quite possibly, the most visible and all encompassing. Reliable electric power is central to our very way of life. It powers our homes and our businesses, charges our cell phones, sometimes our vehicles, allows us to run our air conditioners and plug in our electric blankets, which I needed last night because I had no heat in my house here, so I felt like I was back home.

Senator MANCHIN. Back in Alaska.

The CHAIRMAN. It was good; I slept well.

[Laughter.]

But as more renewables come online and the mix of baseload power changes, our Committee will focus on maintaining grid reliability and resiliency. We will prioritize keeping energy affordable, and we will be working to advance cleaner energy technologies that can help reduce greenhouse gas emissions.

So a focus on what we can do with these technologies, how we can push out the R&D, how we can work to encourage the developments in the CCUS, what we can be doing more of when it comes

to efficiencies, particularly for our buildings. And this has to be a priority, I think, for all of us.

Certainly, in Alaska we view that there is no choice here. In the Arctic, we are seeing warming at twice, over twice, the average of the rest of the Lower 48. It is directly impacting our way of life. Diminishing sea ice and melting permafrost are real world challenges that we are contending with today.

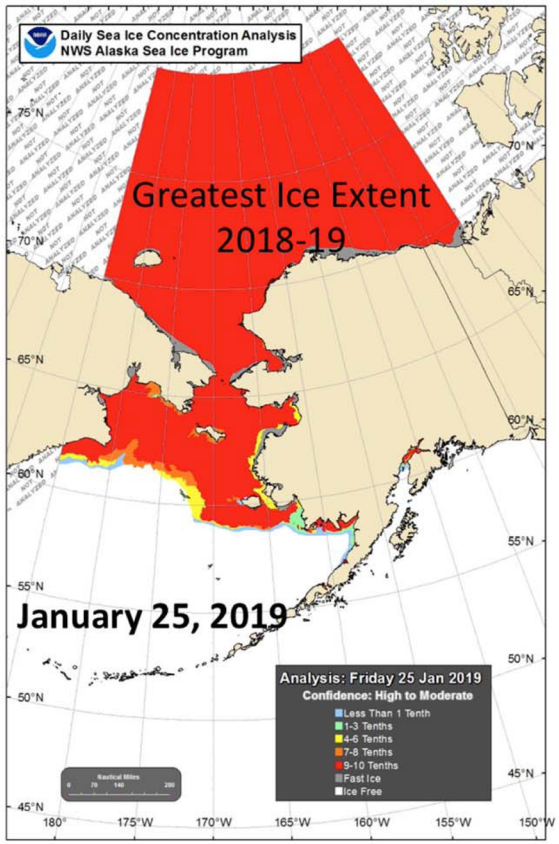
We are seeing wildlife migration patterns that are changing as the bowheads move further north. We are seeing changes within our fisheries as we are seeing different species in more northern waters than we have before. It is impacting subsistence, it is impacting food security, and it is certainly impacting our economy with our fisheries.

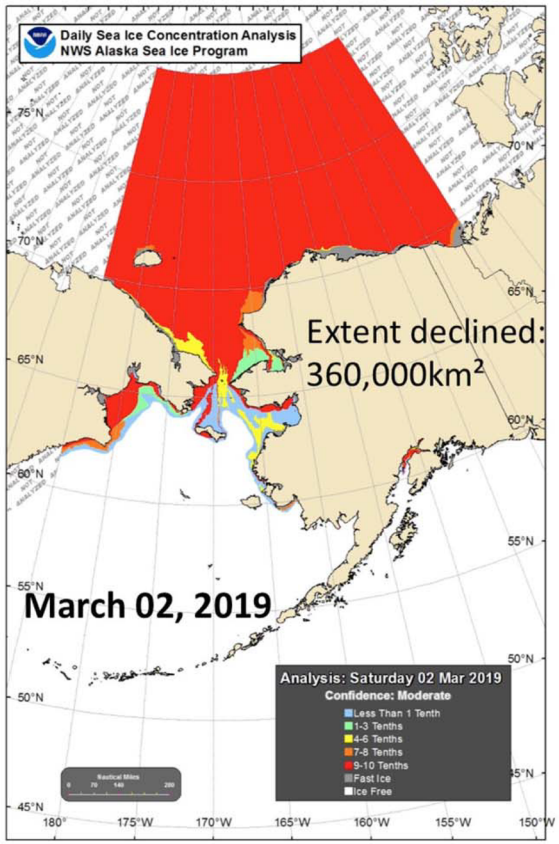
There was a story, just very prominent, in yesterday's clips, and it detailed the drought extent across Southeastern Alaska. Southeast is where I grew up. It is the Tongass National Forest. It is a rainforest. And within Southeast are the communities of Wrangell and Ketchikan, where I lived, and Petersburg. These are hydro communities that are now relying on diesel-powered generation. People are actually having to talk about water conservation, literally, in a rainforest. It is having an impact. The headline of this particular story was "Hatcheries are the Canary in the Coal Mine as Drought Extends across Southeast Waters."

Because what happens is they have the little fry in the hatcheries and they are seeing warmer waters coming down from out of the rivers, and they need to keep these fry cool. So they put them out into the ocean. Well, they are putting them out a full month earlier. So what does that mean then to their ability to survive out there? So it is a very, very real condition and situation.

Yesterday, on the front page of our largest newspaper, the Anchorage Daily News, there was a story about the extent of the sea ice, and how for the first time in many memories we are seeing open waters in and around the area here around St. Lawrence Island and Diomede Island up here.

[The information referred to follows:]


Daily Sea Ice Concentration Analysis
NWS Alaska Sea Ice Program
Greatest Ice Extent
2018-19
January 25, 2019
Analysis: Friday 25 Jan 2019
Confidence: High to Moderate
Less Than 1 Tenth
1-3 Tenths
4-6 Tenths
7-8 Tenths
9-10 Tenths
Fast Ice
Ice Free
75°N
70°N
65°N
60°N
55°N
50°N
45°N
180°
175°W
170°W
165°W
160°W
155°W
150°W

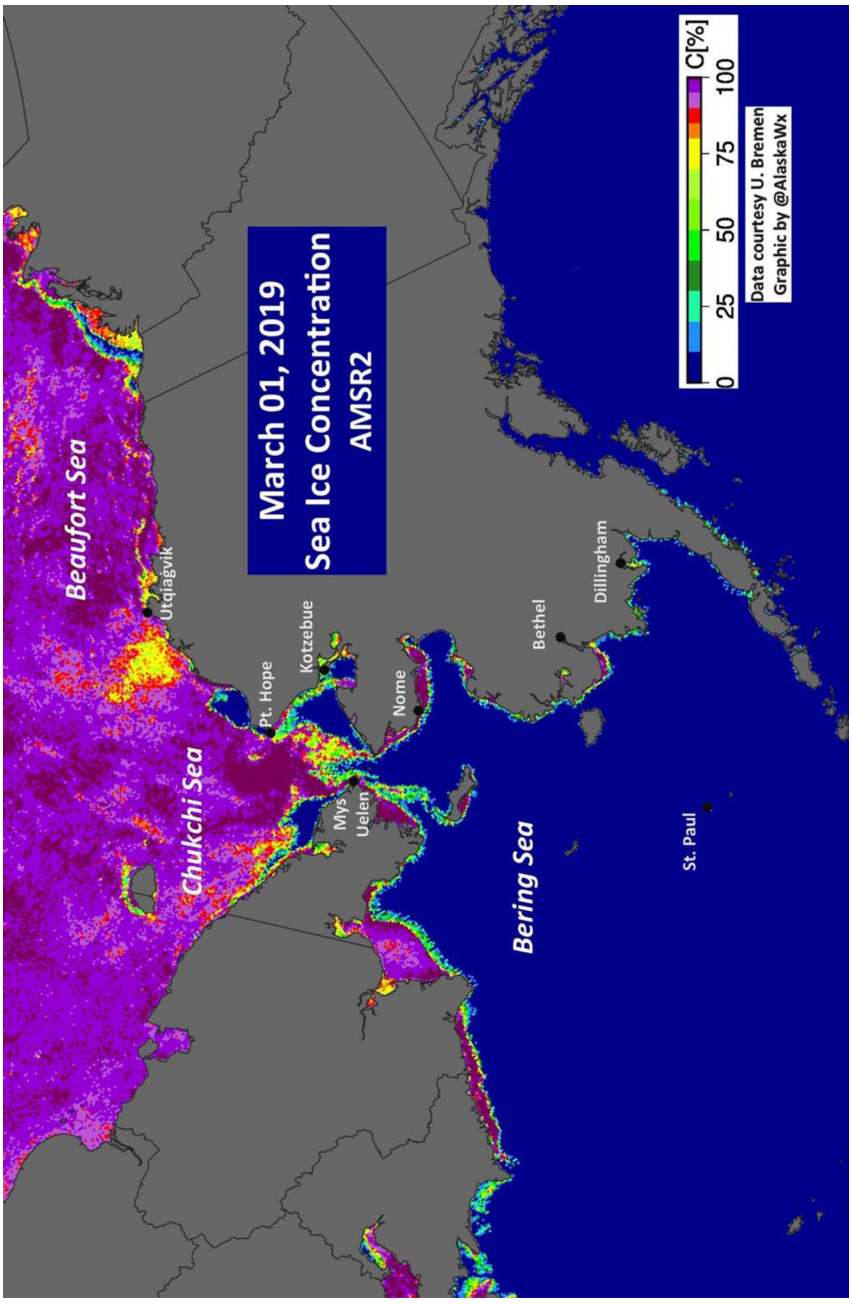

Daily Sea Ice Concentration Analysis
NWS Alaska Sea Ice Program
Extent declined:
360,000km²
March 02, 2019
Analysis: Saturday 02 Mar 2019
Confidence: Moderate
Less Than 1 Tenth
1-3 Tenths
4-6 Tenths
7-8 Tenths
9-10 Tenths
Fast Ice
Ice Free
75°N
70°N
65°N
60°N
55°N
50°N
45°N
180°
175°W
170°W
165°W
160°W
155°W
150°W

The CHAIRMAN. This chart shows the sea ice about a month and a half ago, January 25th. And then just a couple days ago, March 2nd, you have had this much ice that has broken up, pushed off and gone further to the North.

So it is dramatic. It is not just climate change. It is not that it warmed up that quickly but you have a series of conditions that you see with the wind and the warming and the water.

The other map is one that shows, again from the same article, the same graphic by AlaskaWx.

[The information referred to follows:]


March 01, 2019
Sea Ice Concentration
AMSR2
Beaufort Sea
Chukchi Sea
Bering Sea
Utqiagvik
Pt. Hope
Kotzebue
Nome
Mys Uelen
Bethel
Dillingham
St. Paul
C[%]
0
25
50
75
100
Data courtesy U. Bremen
Graphic by @AlaskaWx

The CHAIRMAN. This is the sea ice concentration in the Chukchi and Beaufort, in terms of the depth and the concentration of the ice. But it speaks to the reality that we are facing up North.

I was home this weekend for one of my favorite events, which is the Iditarod race, which is a 1,000-mile, actually 1,100-mile, race really all about tough Alaskans and grit and how humans and animals interact together. It is an iconic race, and the route has changed a little bit as we have seen the conditions on the ground changing.

In the Norton Sound area, where usually the teams will cross the frozen ocean, it makes for a very exciting but really a grueling trek because of the winds that are out there. Well now that is open water and so they have had to reroute the race to hug the shoreline.

So as we deal, again, with these very real realities, it is not just things like a sled dog race. We have a number of communities that need to relocate in order to survive the encroaching seas as we are seeing greater sea ice move out in more open water.

But our reality is that we don't, at this point in time, have a clear or effective federal plan to ensure that can happen on a timely basis. And that is something I hear from my constituents a great deal about.

Another challenge is that many of our remote communities in Alaska are heavily reliant on expensive diesel fuel for heating and power. Integrating cleaner energy technologies, often with a microgrid, can decrease reliance on diesel and provide for greater reliability. It can also reduce costs, which is critical for unlocking local economic opportunities. And of course, it is certainly much better for the environment.

So I am very pleased that as part of today's panel we have Ethan Schutt, a friend, a leader. He is with the Alaska Native Tribal Health Consortium to provide his perspective about many of these challenges and to provide some details about what work is being conducted in Alaska today.

In addition to Ethan, we have Mr. Joe Kelliher, a former Chairman of the Federal Energy Regulatory Commission (FERC) and currently the Executive Vice President of Federal Affairs for NextEra Energy. Mr. Kelliher has been before the Committee many times, but it is good to have you back.

We also have Dr. Susan Tierney. She is with the Analysis Group. We welcome you.

Dr. Kenneth Medlock is the Senior Director for the Center of Energy Studies at Rice University. It is good to have you as part of the panel.

And Ms. Lisa Jacobson, who is the President of the Business Council for Sustainable Energy (BCSE).

I thank each of you for being here.

Now I think it is important to point out, we know here on the Committee that we have jurisdiction in certain areas. We do not have complete jurisdiction over climate change, we recognize that, but we do have a considerable role to play in developing reasonable policies that can draw bipartisan support that I think will be a pragmatic contribution to the overall discussion. What we can add to that conversation about research, about innovation, and effi-

ciency, I think you will likely see these as subjects of further discussion within this Committee.

This morning, we will begin that conversation. I am very pleased and encouraged that in working with Senator Manchin we have been able to have good conversations, the two of us and our staffs, about where we want to lead the Committee in this very, very important area. I appreciate his leadership on this as well.

Senator Manchin.

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

Senator MANCHIN. Thank you, Chair Murkowski, and thank all of you for coming today to be with us at this very, very important meeting.

I might add, this is the first hearing on climate since 2012 in the ENR Committee, almost seven years. We all talk about it every day. We know it is impacting our lives. First hearing. So I want to thank you, Chairwoman Murkowski, because this is excellent timing for this.

Our shared focus on identifying pragmatic solutions to the urgent problem of climate change makes the work of this Committee vital to our nation. I believe it sets a model for working together to come to an agreement on a bipartisan path forward, in spite of partisan rhetoric.

I also want to thank our distinguished panel for joining our Committee to share your insights with us today.

For years I have argued we need to be working from an agreed upon set of facts about the climate crisis in order to move forward quickly with real world solutions that protect our communities and workers from unnecessary economic harm. You really cannot play a game of darts if you can't agree on where the bullseye is. And that is what we are dealing with here.

People—I have never seen in any one town such as this—people will basically set their opinions and try to justify their opinions based on what they want the facts to be, not based on what the facts are and try to work toward an agreed position. To that end, we are seeking to use this hearing to identify what emission reductions the power sector has achieved and what the power sector must do to contribute in near-term and long-term emission targets. I believe the focus must be on the path toward innovative power generation technologies that will keep the lights on, our economies humming and achieve the emission reductions we so desperately need.

First, man-made climate change is real and it is a serious threat to our citizens, to our economy, to our environment and to our national security. In 2016, a devastating flood took the lives of 23 West Virginians, unparalleled in any other time in history in West Virginia. Over the last four years I have asked the White House for emergency funding six times as a result of severe flooding. My office deploys an emergency response page during severe weather, and we have posted it dozens of times over the past few years.

In Alaska, my dear friend and colleague here, Chairwoman Murkowski, there have been 4 communities that needed to immediately pick up and move and 12 more actively planning for a partial or

total community relocation due to climate change, as Mr. Schutt will tell you about in his testimony.

Climate impacts have also forced people to leave their communities permanently in the wake of storms like Hurricane Maria after which nearly 130,000 people left Puerto Rico according to the Census Bureau. And if you just look on the news today what happened in the last couple days as far as horrific tornadoes down in the south and southwest.

According to the Fourth National Climate Assessment, the U.S. has experienced 44 weather and climate disasters since 2015. The cost has neared $400 billion with a B, $400 billion.

Second, all communities, including those in energy producing states like West Virginia and Alaska, are experiencing the harmful impacts of the climate crisis. These impacts are often felt disproportionately in West Virginia communities which are already suffering from the downturn in the coal production, resulting unemployment and negative effects of coal company bankruptcies on retirement and health care benefits. Therefore, the path to a climate solution must offer states like West Virginia opportunities, not additional economic burdens. The Chairwoman and I share a deep concern for our rural communities and seek to use this Committee as a means of identifying and legislating pathways to ensure our constituents have a role in the clean energy future.

And third, the solutions must be grounded in reality which requires a recognition that fossil fuels are not going anywhere anytime soon. The IEA predicts that up to 51 percent of China's power could come from fossil fuels in 2040 depending on energy policies that are adopted. That number could be as high as 57 percent for India. This is the real world we are living in.

The role of fossil fuels in the global economy is growing, and the U.S. must lead the world in pursuing the solutions that will allow us to burn fossil fuels in a cleaner, more cost-effective and more efficient manner.

What we were told by Dr. Birol is that the age of the plants in Asia is about 11 years old for all the fossil fuel, about 11 years is the average. They are going to amortize those plants out. They are going to run them until they are 40 to 50 years of age. That is just the economic facts.

In America, we have plants that are much older. It is much easier for us to convert than it is for Asia, and that is just what we are dealing with today. It does not mean that we should set aside work increasing efficiency or advancing nuclear storage or renewables such as solar, wind and hydropower. But it does mean that we have to double down on innovative solutions for the clean use of fossil energy in the electric, industrial and transportation sectors, and we must do it today.

Just last week, Dr. Birol, the leader of the International Energy Agency, told this Committee that the rest of the world and particularly countries in Asia will continue to use fossil fuels for decades to come. He stated, and I quote, "Last year global CO_2 emissions, once again, increased and the main driver for that increase came from Asia."

As I have said before, just as West Virginians don't want to drink dirty water or breathe dirty air, neither do citizens of other

countries. As India continues to build new coal power plants to provide electricity to more and more of its people, the U.S. should find ways to ensure that they have the technologies and policies needed to eliminate any resulting pollution and that technology is developed and manufactured here in America. That is where we can truly be the game changer.

Similarly, as China becomes the world's largest natural gas importer and continues consuming large amounts of coal and oil, the U.S. should respond to these developments by leading on carbon capture utilization and sequestration technologies.

It is a fact that our country has the greatest energy resource of all. Our brilliant researchers and developers can do and must do the job. That is something nearly every witness we have heard from this year has highlighted.

As Secretary Ernie Moniz has said best, "Clean energy innovation supports malleable national goals, economic competitiveness, environmental responsibility, energy security and national security and it is at the heart of American economic success and optimism."

I am optimistic about our country's ability to innovate and implement climate change solutions, because we fundamentally share these goals and have the know-how to tackle them together.

I look forward to the Committee taking up this discussion about energy innovation and expanding it across all technologies needed to address the climate problem, and we cannot wait another seven years to continue these meetings.

With these facts in mind, I look forward to today's discussion of the trends in the U.S. electric sector, how they affect and are affected by climate change and how this Committee can continue this important dialogue and take action on the technology and policies needed to address it.

With that, Chairman Murkowski, I look forward to our hearing and thank you so much for calling it.

The CHAIRMAN. Senator Manchin, thank you.

We will now turn to our panel. I think I have introduced each of you.

I would ask that you try to limit your comments this morning to about five minutes. Your full statements will be included as part of the record, but this will allow us an opportunity for dialogue afterwards.

With that, we will turn to you, Mr. Kelliher. Welcome.

STATEMENT OF HON. JOSEPH T. KELLIHER, EXECUTIVE VICE PRESIDENT, NEXTERA ENERGY, INC.

Mr. KELLIHER. Thank you.

Chairman Murkowski, Senator Manchin, members of the Committee, I appreciate the opportunity to testify today on the dramatic changes that are occurring in the electricity sector. I appear today on behalf of NextEra Energy, one of the largest electric generators in the U.S., generator with the most diverse electricity supply in the country and the world's leading generator of renewable energy.

The electricity sector is undergoing an unprecedented degree of change. That change has resulted in significant customer benefits, in the form of lower prices, lower price volatility, and improved

operational performance. Our electricity supply mix has become younger, cleaner, more diverse, and more flexible.

A collateral benefit of the transition in our electricity supply mix is that emissions from the sector have declined sharply.

The electricity sector transition is being driven by market fundamentals, including a dramatic increase in U.S. natural gas production, a sharp and sustained fall in natural gas and wholesale power prices, displacement and retirement of inefficient fossil generation, lower than expected demand, the addition of modern, efficient gas generation, and accelerated entry of renewables. Contributing to these market forces are federal and state policies encouraging renewables, as well as stricter environmental requirements on generation facilities. As a result of these factors, the U.S. electricity supply mix has changed significantly over a very short period and there is now more diversity in the U.S. electricity supply than at any point in the past.

The coal share of our electricity supply mix has declined from 47 percent in 2005 to 27.5 percent last year. The natural gas share rose from 22 percent to 35 percent, and the wind and solar share quadrupled, now accounting for roughly 11 percent of our supply.

FERC wholesale competition policy played a critical role in this transition, and in my view, competition policy, wholesale competition policy, has been a major success.

The same cannot be said about retail competition, however. Retail competition has largely been limited to states that historically had very high retail rates. And in many of these states, retail competition has been a failure, at least for residential customers, resulting in higher rates from competitive suppliers than those rates charged by regulated utilities.

One of the primary drivers of the transition in the electricity sector is the surge of new technologies. The electricity industry is now experiencing a greater degree of technology entry than at any point in the last 100 years.

While federal and state policy did encourage renewable energy, renewable entry is the result of technological improvements and lower cost. Since 2009, the cost of wind generation has declined 69 percent and solar PV costs are down 88 percent. The low cost of solar is encouraging even faster entry.

For example, recently Florida Power and Light, one of our principle subsidiaries, announced a "30 by 30" plan to install more than 30 million solar panels by 2030, making Florida a world leader in solar energy.

Battery storage is a breakthrough technology that promises many benefits. Storage can provide power during grid failures and weather-related outages, it can relieve transmission congestion, and it can integrate renewables. It really is the most flexible product that we see in the electricity industry. Storage economics have also improved dramatically with battery costs falling 80 percent since 2010.

Now increasingly, electricity companies are looking for a way to combine these new technologies in order to better serve customers. Recently, our competitive power company, our other principle subsidiary, NextEra Energy Resources, announced a partnership with Portland General Electric in Oregon to develop the nation's first

project that integrates wind and solar generation with storage, at the same site, the Wheatridge Renewable Energy Facility.

The changes that are sweeping across the industry have not just lowered prices, they've lowered emissions. Electricity sector emissions of carbon in 2017 were 28 percent below 2005 baseline and that compares very favorably to the goals of the Clean Power Plan which were a 32 percent reduction by 2030.

Importantly, the primary cause in the decline of electricity sector emissions are generation retirements and lower output from higher-emitting resources attributable to market fundamentals. New environmental regulations were only a secondary factor in these emissions reductions along with lower electricity demand.

Market fundamentals have resulted in the retirement of a host of inefficient fossil plants since an inefficient plant not only uses more fuel to produce the same electric output, it produces greater emissions. These retirements have had an outsized impact on emissions reductions.

In conclusion, U.S. electricity markets are undergoing a fundamental transition driven by market fundamentals. The transition is likely to continue, producing an increasingly diverse and more reliable electricity supply and this transition has resulted in environmental benefits, from sharply lower emissions from a generation fleet that is younger, cleaner, more efficient, more diverse, and more flexible in performance.

Thank you very much. And I look forward to answering your questions.

[The prepared statement of Mr. Kelliher follows:]

Testimony of Joseph T. Kelliher
Executive Vice President – NextEra Energy, Inc.
Before the Committee on Energy and Natural Resources
United States Senate

"Electricity Sector in a Changing Climate"

March 5, 2019

Introduction

Chairman Murkowski, Members of the Committee, I appreciate the opportunity to testify today and offer my perspective on the dramatic changes that are occurring in the electricity sector. I appear today on behalf of NextEra Energy, one of the largest U.S. electric generators, and the generator with the most diverse supply mix. NextEra Energy is one of the few national electricity companies in the U.S., operating in every regional power market in the country. I offer the perspective of NextEra Energy and a former Chairman of the Federal Energy Regulatory Commission (FERC).

NextEra Energy is a leading clean energy company with consolidated revenues of more than $16 billion, 49,000 megawatts of generating capacity, and 14,000 employees in 36 states and Canada. NextEra Energy is the largest U.S. electricity company in the world by market capitalization. Headquartered in Juno Beach, Florida, NextEra Energy's principal subsidiaries are Florida Power & Light Company, which serves more than five million customer accounts in Florida and is the largest electric utility in the United States, Gulf Power Company, and NextEra Energy Resources, a competitive power company that is world's largest generator of renewable energy from the wind and sun. NextEra Energy generates clean, emissions-free electricity from eight nuclear power units in Florida, New Hampshire, Wisconsin, and Iowa.

I commend you for holding this hearing. The electricity sector is undergoing an unprecedented degree of change. That change has resulted in significant customer benefits, in the form of lower prices, lower price volatility, and improved operational performance. Our electricity supply mix has become younger, cleaner, more diverse, and more flexible. A collateral benefit of the transition in our electricity supply mix is emissions from the electricity sector have declined sharply as a result. While these benefits are significant, there have been impacts associated with the retirement of uneconomic generation.

Changes in U.S. Electricity Sector

As someone who has been involved in the electricity sector in one role or another since the late 1980s, it is striking to see the degree and pace of change in the electricity sector. The U.S. electricity industry is in the middle of a fundamental transition. This transition is being

driven by market fundamentals, including a dramatic increase in U.S. natural gas production from the shale gas revolution, the resulting sharp and sustained fall in natural gas prices and significant decline in wholesale power prices, displacement and retirement of inefficient coal, natural gas and oil-fired generation, lower than expected electricity demand, the addition of modern, efficient natural gas generation, improvements in wind and solar technology and accelerated entry of renewables, and the introduction of other technologies, especially storage. Contributing to these market forces are federal and state policies encouraging renewables, and stricter environmental requirements on generation facilities.

Of these factors, the most important by far have been low natural gas prices in concert with the addition of highly efficient new gas generation. When combined with lower demand growth, the result is low wholesale power prices, rendering generation from many older, inefficient facilities uneconomic. Importantly, the sharp fall in natural gas prices changed the longstanding relationship between coal and gas generation, making gas generation significantly lower cost than coal for the first time – that is the real game changer.

There has been sizeable retirement of inefficient and uneconomic older coal and natural gas generation facilities, some retirement of uneconomic nuclear units, and large additions of modern, efficient natural gas and renewable energy generation. As a result, the U.S. electricity supply mix has changed significantly over a relatively short period, and there is now more diversity in U.S. electricity supply than ever before. The coal share of our electricity supply mix declined from 47% in 2005 to 27.5% in 2018, the natural gas share rose from 22% to 35% over the same period, and wind and solar quadrupled, now accounting for 11% of our supply. Overall, the mix of U.S. electric generation facilities is younger, more efficient, more divese, and more flexible than ever before.

These changes have been so significant to have raised questions about whether generation retirements are being driven by market fundamentals or by federal or state policy, and whether the retirement of uneconomic generation poses a threat to electric system reliability. The evidence strongly suggests that the primary factor driving retirements has been market fundamentals, not regulatory policy, and there is no evidence to suggest the retirement of uneconomic generation poses a threat to electric reliability. Because the transition is driven by market fundamentals, it can be expected to continue.

While there are concerns in some quarters that future retirements may result in a loss of electricity supply diversity, the reality is the transition has made our electricity supply much more diverse and is likely to result in even greater diversity in coming years.

The retirement of inefficient and uneconomic generation is a natural aspect of a competitive market. Given the outlook for U.S. natural gas supply and prices, low demand growth, and continued improvements in wind and solar efficiency and cost, the pressure for uneconomic facilities to exit may not relax.

FERC wholesale competition policy played a critical role in this transition. Lowering costs was a primary goal of competition policy in both the electricity and natural gas industries. Competition produced the shale gas revolution, successfully shifted risk away from customers to market participants, and facilitated deployment of new technologies.

In my view, wholesale competition policy has been a major success. The same cannot be said about retail competition. Retail competition has largely been limited to states that historically had very high retail rates, with the exception of Texas, where consumers are mandated to choose a competitive supplier. In many states, retail competition has been a failure, at least for residential customers, resulting in higher rates from competitive suppliers than the rates charged by regulated utilities. Perhaps because of these outcomes, participation by residential consumers in retail programs has been declining since 2014. The real beneficiary of these retail programs appears to have been industrial and other large customers.

There are some who argue the electric sector transition is the result of systemic "market failure" that must be corrected. It should be recognized that the "market failure" these critics are trying to remedy is low prices resulting from market fundamentals. Their "solution" is to raise prices charged by a select few, which would tend to suppress prices for everyone else, discouraging the entry of new, more efficient economic generation. In the end, these types of proposals are designed to shift risk away from generators back to customers, contrary to a primary goal of competition policy. In effect, subsidies grant the owners of uneconomic generation facilities a safe haven from the hazards of competitive markets.

New Technologies

One of the primary drivers of the transition in the electricity sector is the surge of new technologies, including generation, storage, and demand response technologies. The electricity industry is experiencing a greater degree of technology entry than at any point over the last hundred years.

As noted earlier, the renewable energy share of the U.S. electricity supply mix has quadrupled since 2005. That is a remarkable degree of change in such a short period. Since 2013, more than half of new electricity generation capacity added in the U.S. has been wind and solar energy. While federal and state policy encouraged renewable energy, these policies encouraged competition between renewable energy technologies and companies, and the lower cost technologies and more competitive companies have tended to prevail over time.

The surge in renewable energy entry is the result of technological improvements in cost and performance. Since 2009, the cost of wind generation has declined 69%. Even more dramatic is the decline in solar PV costs, down 88% since 2009. Many utilities are purchasing more renewable energy than required under state policy, because it makes economic sense.

Historically, economies of scale have been an important consideration to providing electricity at a reasonable cost. Economies of scale are still important, even with these newer

clean energy technologies. As a case in point, Florida Power & Light recently announced a "30 by 30" plan to install more than 30 million solar panels by 2030, making Florida a world leader in solar energy. Small scale private rooftop solar can cost 2 to 5 times as much as utility scale solar generation, and is highly dependent on above-market rates and cross subsidies from nonparticipating customers.

But storage may be the most exciting new technology. Electricity is the only commodity that cannot be readily stored, and historically the only way to storage electricity was in the form of water at a pumped storage project. But battery storage is a breakthrough technology that promises many benefits. Storage can respond very quickly, and is a very flexible product that can be tailored to meet particular system needs and customer preferences. At a very high level, storage can reduce price volatility, and make supply and demand flatter. Battery storage also has many uses. Storage can provide power during grid failures and weather-related outages, can relieve transmission congestion, and can integrate renewables. Storage economics have also improved dramatically, battery storage costs falling 80% since 2010.

Increasingly, electricity companies have become technology companies that deliver power and are looking to combine technologies to improve performance. Last year, Florida Power & Light unveiled the Nation's largest combined operating solar and storage project at Babcock Ranch in Florida. More recently, our competitive power company, NextEra Energy Resources, announced a partnership with Portland General Electric in Oregon to develop the Nation's first project that integrates wind and solar generation and battery storage, the Wheatridge Renewable Energy Facility. We expect these sort of innovative combined projects will become more common in future years.

There are many other technologies that benefit customers. For example, smart meters provide real time data that allows utilities to see outages in real time, pinpoint them quickly, and respond and restore service much faster than in the past.

Energy Infrastructure

A strong energy infrastructure has been a critical foundation for the electric sector transition. Today's electric grid was developed in the past to deliver yesterday's electricity supply, so as our electricity supply mix changes, we need a different grid, one capable of delivering more renewables and new, efficient natural gas generation, while accommodating the retirement of older, uneconomic generation facilities. Changes in the U.S. electricity supply mix were only possible because of robust investment in transmission, and new investments in transmission must keep pace to support the continued transition of our generation fleet. New interstate natural gas pipeline infrastructure enabled the Nation to secure the benefits of the shale gas revolution and facilitated the electricity sector transition.

This Committee has dedicated a lot of attention to studying questions related to the resilience of the U.S. electricity industry. It is quite clear that the key to resilience is the delivery system, the distribution and transmission system. Nearly all outages result from failures of the

local distribution or transmission system, and fuel supply emergencies account for virtually no loss of service. For that reason, a more robust power grid and interstate pipeline network will do more to strengthen energy delivery system resiliency than any other action.

Improving resilience through strengthening energy infrastructure will take significant level of investment. Estimates are that $100 billion will be invested in electricity transmission projects over the next five years. Regulatory policy plays an important role in securing the infrastructure investment and affects the level of risk associated with that investment.

Emissions from Electricity Sector

The changes that are sweeping across the electricity sector have not just lowered prices, they have lowered emissions. Electricity sector emissions of CO2 in 2017 were 28% below a 2005 baseline. SO2 and NOx emissions have experienced even sharper declines.

Importantly, the primary causes in the decline of electricity sector emissions over this period are generation retirements and lower output from higher-emitting generation resources attributable to market fundamentals: the steep fall in natural gas prices, the addition of new, efficient natural gas generation and the surge of new renewable resources.

New air, water, and solid waste environmental regulations were only a secondary factor in emissions reductions, with lower electricity demand being another secondary factor. This may not be intuitive and requires some explanation of the relative economics of coal and gas generation, and how the changing relationship of coal and natural gas pricing affected older, less efficient fossil generation, especially smaller, older, inefficient coal plants.

When natural gas prices were high, an inefficient coal plant could produce electricity more cheaply than the most efficient natural gas power plant. But the shale gas revolution drove down natural gas prices, reversed the longstanding price relationship between natural gas and coal, and made inefficient coal and gas plants uneconomic, with no prospect of operating profitably as long as gas prices remained low. This was true even without considering the impact of compliance with new air, water, and solid waste environmental regulations. These fundamental economics led to widespread retirement of uneconomic fossil generation. The units retired tended to be older and smaller fossil plants. The average age of coal, natural gas and oil power plants plants retired through 2017 was 59, 44, and 46 years, respectively.

An inefficient power plant not only uses more fuel than an efficient plant to produce the same electrical output, it produces greater emissions. For that reason, the retirement of inefficient fossil plants has had an outsized impact on emissions reductions. Environmental regulations put added pressure on uneconomic coal plants. Many older, inefficient coal power plants without controls on mercury faced additional cost pressures as a result of the Mercury and Air Toxics rule. The tipping point for some plants may have been the cost of complying with new environmental regulations, but the primary cause for generation retirement was economics attributable to the shale gas revolution.

I discussed the benefits of battery storage earlier. There are potential emissions benefits here as well, to the extent storage displaces peaking units that tend to be relatively inefficient and high emitting. Some estimates are that half of some peaking units that are 30-50 years old may retire in the next 10 years.

Conclusion

In conclusion, U.S. electricity markets are undergoing a fundamental transition driven primarily by economics, the result of low cost natural gas produced by the shale gas revolution combined with increased energy efficiency, lower demand growth, and low wholesale power prices. The transition has been marked by an increase in new, more efficient natural gas generation, a significant increase in ever-lower cost wind and solar generation, and the retirement of inefficient, uneconomic generation. This transition is likely to continue, producing an increasingly diverse and more reliable electricity supply. While this transition has had some impacts, it is delivering significant benefits to the consumers. This transition has also resulted in significant environmental benefits, from sharply lower emissions from a generation fleet that is younger, cleaner, more efficient, more diverse, and more flexible in performance.

The CHAIRMAN. Thank you, Mr. Kelliher.

Mr. Schutt, welcome. Thank you for traveling all this way.

STATEMENT OF ETHAN SCHUTT, CHIEF OF STAFF, ALASKA NATIVE TRIBAL HEALTH CONSORTIUM

Mr. SCHUTT. You're welcome. I'm happy to be here. Thank you for inviting me to provide perspective from Alaska.

My name is Ethan Schutt. I'm the Chief of Staff for the Alaska Native Tribal Health Consortium. We serve in Anchorage in operating the Alaska Native Medical Center which is a large hospital in Anchorage, and then we also support a statewide health system serving Alaska Native American Indian IHS beneficiaries.

In that role we also have a Department of Environmental Health and Engineering that assists in environmental health matters which is primarily clean water and sewer projects in rural Alaska. Most, the vast majority of the communities we serve in that capacity are not road connected, meaning that they have seasonal barge access and then everything else comes and goes by airplane.

In that environment you have extremely high costs for energy, and it also happens to be the place where climate change impacts are most dramatically felt. Many of those communities, again, almost all of them, are coastal or on rivers. And with the dramatic changes in seasonal patterns and ice conditions that Senator Murkowski showed at the beginning of the hearing here on the map, those dramatic changes in ice conditions have very profound impacts on communities and their infrastructure. It's causing dramatic changes to coastlines.

I mentioned in my written testimony that there has been coined a new word in the federal emergency management lexicon to describe the condition where permafrost is melting so rapidly that it creates dramatic effects at the surface. Largely, this again happens at the coastal area at this point, but it is a dynamic situation.

Senator Murkowski also mentioned something in my written testimony about the number of communities that are affected that require immediate action. There are officially four communities that need complete community relocation at this point because of the threat of storm surge or coastal erosion and the dramatic, life-threatening conditions that come along with that condition. There's also, officially, a dozen, 12, that are just behind that.

I think the condition on the ground is so dramatic that those numbers are not numbers that I'm confident in. I think those numbers change day to day with the dramatic retreat of the seasonal sea ice still well within the winter storm system in Western Alaska, and I think we will see additional dramatic coastal erosion and storm-caused problems in our coastal communities.

We address these issues through a number of adaptation measures, specifically permafrost protection through the insulation of these active/passive systems that help preserve the permafrost underneath community infrastructures so that the ground underneath the community does not melt or at least the ground underneath the community infrastructure does not melt. We also work with coastal protection and river bank protection, trying to protect the banks of these communities.

In addition, we are involved at some level in mitigation. I don't proclaim us to be the leader in mitigation activities in Alaska, but we do assist our rural communities in installing renewables and addressing conservation and efficiency matters, particularly with the water and sewer utilities.

These communities spend an inordinate amount of their disposable income and community income on energy, and a large portion of that goes into actually keeping the water in the water and sewer system thawed and not frozen. It turns out that often there's inefficiencies in how those systems are installed or operated and basic repairs and maintenance can save communities 50 percent of their annual budget on their water and sewer system for things like running too much heat tape and having it on 24/7/365 when you really only need it during certain cold periods. So our engineers help these communities by assessing those conditions and rectifying those small operational inefficiencies or installing new equipment and repair.

I think that that nexus between water and energy is important as a policy matter as this Committee considers energy and emissions—there's an extraordinary nexus between water and energy. And one of the facts I learned a couple of years ago was that as California went through its extreme drought period here a couple of years ago, it turns out that the water conservation measures saved more energy than all of the other state investment in energy conservation directly. And so that single fact highlights the need to address multiple sectors and to pay close attention to energy and water.

Thank you for my time.

[The prepared statement of Mr. Schutt follows:]

Ethan Schutt, Chief of Staff
Alaska Native Tribal Health Consortium

Senate Energy and Natural Resources Committee
Hearing on Electricity Sector in a Changing Environment

Good Morning. Thank you for the opportunity to provide input on behalf of the Alaska Native Tribal Health Consortium (ANTHC) My name is Ethan Schutt and I am the Chief of Staff for ANTHC. ANTHC is a state-wide consortium of tribes and tribal organizations in Alaska that operates the Alaska Native Medical Center in Anchorage in partnership with Southcentral Foundation. ANTHC also operates a number of specialty clinics, statewide programs through telemedicine, and educates village-based providers.

Formed in 1997, ANTHC is dedicated to the vision that Alaska Native people are the healthiest people in the world. As the largest tribal health organization in the United States, the Consortium's nearly 3,000 employees deliver world-class medical, community, and environmental health services to the more than 160,000 Alaska Native and American Indian people residing in Alaska. ANTHC provides comprehensive specialty medical services at the Alaska Native Medical Center; wellness and prevention programs; disease research and prevention; rural health provider training; telehealth services; and essential operational, technical, and logistical support for our tribal health partners in Alaska.

In addition, ANTHC's Division of Environmental Health and Engineering (DEHE) provides planning, design, construction, and operations support of public health infrastructure—including safe water, sanitary waste disposal, and energy efficiency upgrades—throughout Alaska. Providing vital public health facilities that provide clean water and sanitary sewer systems for remote communities with no road access and harsh climates makes for unique engineering challenges, including extremely high energy usage and high energy costs.

Through our DEHE programs and our interactions with people in communities across Alaska, we see and help address both the dramatic and the subtle impacts of climate change. As we visit here this morning, there are 184 of 213 traditional Alaska Native communities that are environmentally threatened to some degree by flooding, erosion, storm surge, permafrost melt or other climate change-related conditions. Of those communities, 31 are imminently threatened, 12 are actively planning for partial or total community relocation and 4 need to immediately move the entire community—including all of the community infrastructure, housing, and public buildings—to escape life-threatening conditions. Of the 4 in dire and immediate threat, only 1 is far enough advanced in planning, permitting and funding to be in the process of a physical move: the village of Newtok is partially relocating to a new village site called Mertarvik, in the first of a multiple phase, whole-community relocation.

The climate change situation in Alaska and the rest of the circumpolar north is so dynamic that it requires new language to describe phenomenon that were unknown less than a generation ago. For instance, there is now a new word recognized in the federal emergency management

lexicon—a word so new to English usage that you have to find your way to the third page of a Google search to find it referenced as described here. "Usteq" is from the Yup'ik word which roughly translates as "surface caves in." Usteq was coined to describe the compounding influences of thawing permafrost, flooding, and erosion. During an usteq evnet, permafrost thaw—a process that was previously a slow, developing hazard—becomes a rapid, high-consequence hazard. The permafrost layer that previously supported the surface as an invisible near-surface foundation thaws rapidly, liquifies, caves in and collapses—usteq. Often usteq is also associated with riverine or coastal erosion where the thawed and slumped surface is quickly eroded away. Although communities have already begun to experience the effects of usteq, it was not formally recognized as a *unique* hazard or formally named until it was included in the 2018 update to the Alaska Statewide Hazard Mitigation Plan, a document required by the Federal Emergency Management Agency (FEMA) as a condition for receiving non-emergency disaster assistance.

Not all of the serious impacts of climate change are as obvious to those who are not intimately familiar with rural life in Alaska. Sea ice that historically protected shorelines and communities from fall and winter storms is thinner and forms later, exposing vast swaths of Alaska's western and northwest arctic coasts to the battering of high winds and storm surge. The seasonal patterns of animals used as traditional food sources has dramatically changed in both timing and location. And winter travel has become hazardous due to poor and unpredictable ice conditions on rivers and lakes.

Rural Energy Initiative

The high cost of energy coupled with the intensive energy needs of sanitation systems across rural Alaska directly threaten the important health benefits provided by clean water and sanitary sewer service. Unlike most systems in the United States, Arctic and sub-Arctic sanitation systems common to Alaska require the constant addition of heat from oil-fired boilers and electricity for pumps that maintain circulation of water in order to keep water and sewer systems running in regions that can see temperatures colder than minus fifty degrees. Energy costs make up, on average, 40 percent of the total cost of operating public sanitation in rural Alaska, where heating fuel costs over $10 per gallon in some locations. The high price of fuel results in water and sewer bills in rural Alaska that range from $80 to $250 per month per household; that's five times the national average and well above the Environmental Protection Agency's (EPA) recommended median household income threshold for customer affordability. While some operating costs for rural sanitation systems, such as labor, regulatory compliance and replacement parts, remain relatively fixed; reducing the cost of energy represents the most significant opportunity to make water and sewer services more affordable and, therefore, more sustainable for rural communities in Alaska.

Recognizing the essential role affordable and sustainable energy plays in rural communities, ANTHC has developed the Rural Energy Initiative—a program focused on reducing operational costs of rural water and sewer systems through energy efficiency and renewable energy solutions. To date, ANTHC has completed energy projects in 45 rural Alaskan communities. Funding for these efforts has been provided by three primary sources: the Denali Commission,

United States Department of Agriculture (USDA) Rural Development's Rural Alaska Village Grant Program 2% set-aside for technical assistance and training, and the State of Alaska. However, current funding levels will leave over 100 communities across rural Alaska with unfulfilled energy-saving potential, placing the health and the future of residents and their community in jeopardy.

The Rural Energy Initiative reduces water and sewer costs through a holistic, four-phased approach:

1. Conducting energy audits to model energy use and identify opportunities for savings
2. Implementing appropriate energy efficiency improvements and operator training
3. Reducing operating costs when possible using available renewable energy opportunities
4. Tracking performance and impacts of changes in the plant, operator behavior, and renewable energy approaches

ANTHC and its DEHE program continue to address the impacts of climate change on a daily basis across Alaska. Thank you for the chance to provide input on this important matter.

The CHAIRMAN. Thank you, Mr. Schutt.
Dr. Tierney, welcome.

STATEMENT OF DR. SUSAN F. TIERNEY, SENIOR ADVISOR, ANALYSIS GROUP, INC.

Dr. TIERNEY. Good morning, Chairman Murkowski—and I mispronounced, I dropped a syllable, I apologize—Murkowski, Ranking Member Manchin—I think I got the right number of syllables on that one—members of the Committee, it's such a pleasure to be here. Thank you for inviting me to join the panel. I personally, as a citizen of the United States, appreciate that you are holding this hearing on climate change. So thank you very much.

I would like to talk a little bit about the electric sector, but Mr. Kelliher has said almost everything that I was going to say. My written statement includes a number of charts and figures which amplify those points, so I'll try not to repeat.

But I will say that I would agree with him that there is very good news in terms of what we're seeing happening in the electric sector. As he said, the system is much more diverse than it was in the past. We have retained incredible, reliable service, including in Hawaii where you are on the edge of renewable energy and other things. So it's great.

Consumers are seeing electricity bill savings associated with the changes we've seen in the past and for every dollar we spend on electricity, we are getting much more gross domestic product output. This is a great piece of news for the American economy.

And of course, all of that is happening at the same time that emissions have declined in the electric sector by 28 percent since 2005. That is great news.

The power sector emissions are coming from almost every state in the United States which is also great news. This gain in efficiency, productivity of our electricity dollars are spreading across the United States and that's great.

There are many developments that are underway that are contributing to these. You have heard about those. States have adopted renewable energy standards. States have adopted goals for greenhouse gas emissions. They have also innovated. You have supported technology research at the Department of Energy. All of that is great.

And we also see corporations, cities, counties, doing a tremendous amount of work to meet their own commitments and people like me have rooftop solar coming up all over the country which is great. And that's, in part, because the costs of those technologies are going down. And again, I think that that is a product of the innovation that we have spawned in this country.

Another point I want to mention is that every indication in surveys of the American public is that people believe climate change is occurring and that increasingly Americans at the level of 75 percent think that it is a problem. So it's a strong word of encouragement for the actions of this Committee and others to think about what to do.

But even with the successes that we've seen, there is not all good news. And the troubling news is that not everyone has benefited from these changes as Ranking Member Manchin has just said.

There have been parts of the country which have seen dislocations and there is much, much more to do.

So first, the electric sector is both a contributor to the problem and a helper to the problem, but it is also affected tremendously by climate change itself. And so, there is a lot of infrastructure that is at risk associated with flooding, sea level rise; a lot of electric infrastructure is on the coasts, in low level waterways. And so, the thing that we're depending upon to help us actually is exposed to climate change at the same time.

Additionally, climate change, greenhouse gas emissions reductions are not occurring as fast as they need to. In fact, in the last year, emissions in the electric sector went up for the first time in a decade. And so, that's a little bit troubling news. And so, we need, looking ahead, to see more significant action. And that's why I'm very glad that you're holding this hearing and your others to look at solutions coming up.

So the current progress we've made, I think, is so helpful because it tells us what is doable and it helps us be ambitious in terms of what we can do next.

One of the things that I want to underscore is a point that Ranking Member Manchin said about the importance of looking across the board at a variety of portfolios. One of the things that I would encourage the Committee to do is not to prematurely limit options that are needed in order to address this issue. Everything that I have read from the literature on decarbonizing the electric sector which is a cheaper way to address the emissions of greenhouse gases, that's needed in order to electrify other sectors such as the vehicle sector. And all of those contribute to an approach. But if we do that, the literature says, we need to keep all options on the table at the moment.

So, thank you very much.

[The prepared statement of Dr. Tierney follows:]

Testimony of Susan F. Tierney, Ph.D.
Senior Advisor
Analysis Group, Inc.
Denver, Colorado

Before the U.S. Senate
Committee on Energy and Natural Resources

Full Committee Hearing to
Examine the Electric Sector in a Changing Climate

March 5, 2019

Testimony

Good morning, Chairman Murkowski, Ranking Member Manchin, and Members of the Committee. My name is Susan Tierney,[1] and I am a Senior Advisor in the Denver office of Analysis Group, an economic consulting firm where I specialize on policy, economics and environmental issues associated with the electric industry.

Thank you for inviting me to testify at this important Senate hearing on conditions in the electric sector in a changing climate. I am testifying on my own behalf at today's hearing.

I understand that the Committee seeks to foster a constructive discussion on the need to address climate change, on its impacts on the electric sector, and on the need for workable solutions and progress toward reducing greenhouse gas ("GHG") emissions related to power production and other energy uses. The electric sector has a critical role to play in those solutions, so this is an important area of inquiry by the Committee and by others in Congress.

At the hearing, I have been asked to describe trends in the U.S. electric industry that are affecting emissions of greenhouse gases, and I am honored to have this opportunity to help inform the record today.

It is well understood that the U.S. electric power system is undergoing a major transition. Over the past decade, changes have been driven predominantly by low natural gas prices, which have led to increased use of gas for power generation. Declining costs of wind and solar projects, along with flat demand—even as the economy has grown—have also had significant impacts on the changing electricity mix.

Figures 1 and 2 show the changing resource mix in the nation's electricity supply since 1990 (Figure 1) and the more recent trends in each fuel source's role in electricity production between 2005 and 2017 (Figure 2).

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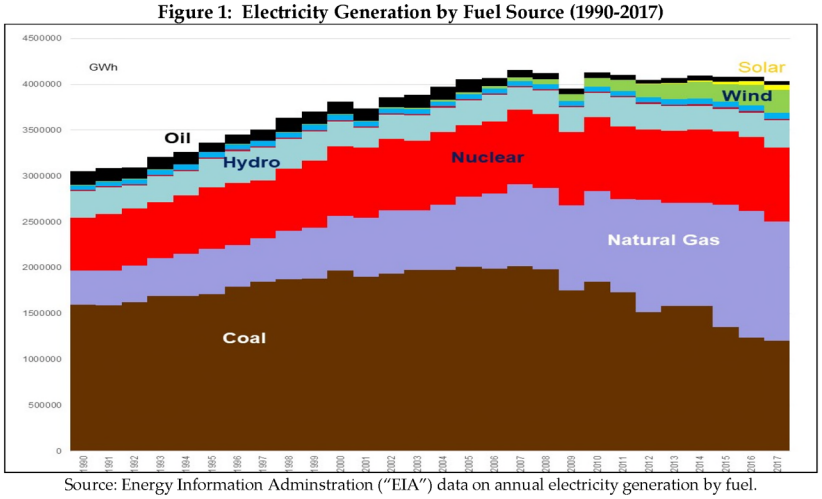
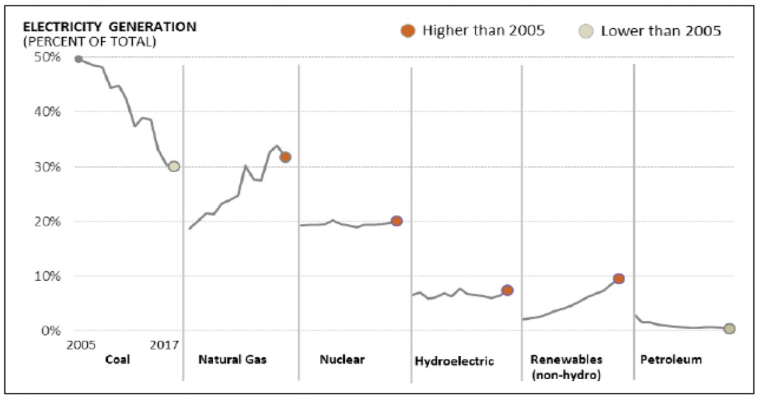
[1] I have provided my bio at the end of this testimony.

Figure 1: Electricity Generation by Fuel Source (1990-2017)



Source: Energy Information Adminstration ("EIA") data on annual electricity generation by fuel.

Figure 2: Percentage of Electricity Generation by Fuel Type (2005-2017)

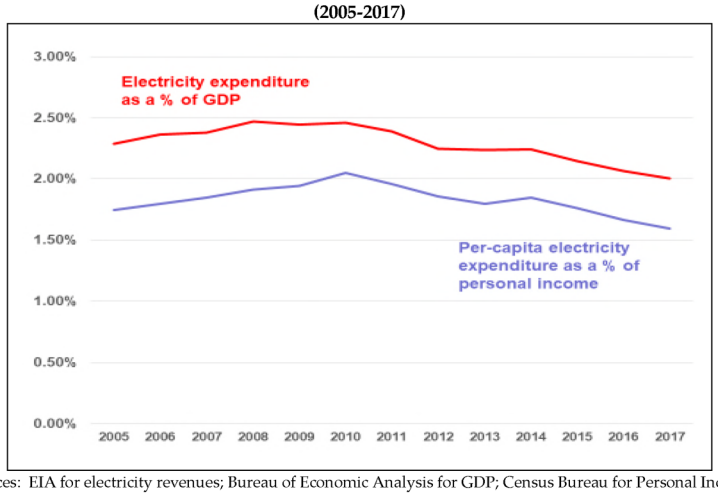


Source: Congressional Research Service ("CRS"), "U.S. Carbon Dioxide Emissions in the Electricity Sector: Factors, Trends, and Projections," January 7, 2019.

There is much good news in these trends: Today's electric system is more diverse than in the past (as shown in Figure 2), continues to provide highly reliable service to consumers, is enabling greater

economic bang per buck[2] spent on electricity (Figure 3), and has contributed positively to lowering consumers' electricity bills in the past decade (Figure 3).

Figure 3: U.S. Electricity Payments Relative to Gross Domestic Product and Personal Income (2005-2017)

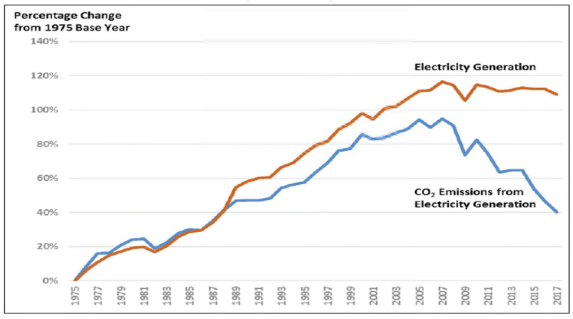


Sources: EIA for electricity revenues; Bureau of Economic Analysis for GDP; Census Bureau for Personal Income.

Another positive consequence of these changes is that carbon emissions from U.S. electricity production have declined substantially over this past decade. Figure 4 shows that even as electricity generation and use have remained relatively flat over the past decade, carbon dioxide (CO_2) emissions from power production declined by approximately 28 percent from 2005 through 2017.[3] So far, these reductions are in line with international commitments that U.S. has made in recent years.[4]

[2] Measured in terms of dollar of Gross Domestic Product ("GDP") per dollar spent on electricity.
[3] EIA, "Carbon dioxide emissions from the U.S. power sector have declined 28% since 2005," *Today in Energy*, December 21, 2018; Congressional Research Service, "U.S. Carbon Dioxide Emissions in the Electricity Sector: Factors, Trends, and Projections," January 7, 2019, page 8 (hereafter "CRS CO_2 Report").
[4] Under the Paris Agreement, "the United States pledged (in 2015) to reduce GHG emissions by 26%-28% by 2025 compared to 2005 levels.7In addition, pursuant to the Copenhagen Accord, the United States pledged (in 2009) to reduce GHG by 17% below 2005 levels by 2020." CRS CO^2 Report, pages 1-2.

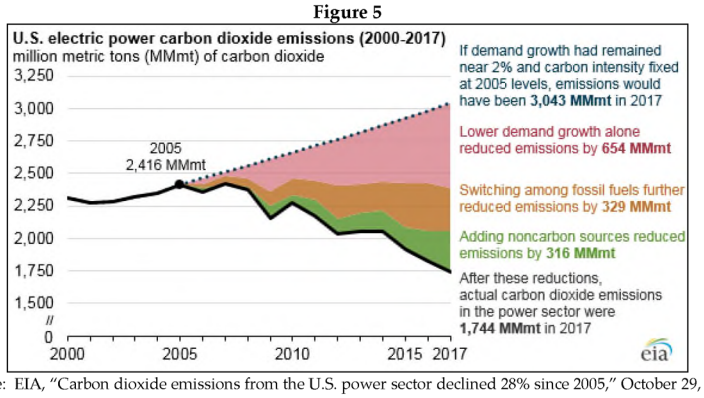
Figure 4: Percentage Change in Electricity Generation and Power-Sector CO_2 Emissions (1975-2017)



Source: CRS CO_2 Report.

Power-sector CO_2-emission reductions have resulted from multiple factors, as indicated in a recent analysis by the EIA. As shown in Figure 5 (excerpted from EIA's report), emissions reductions since 2005 from power generation stem from flat electricity demand (relative to prior norms of electricity growth that were closer to 2 percent per year), from switching among fossil fuels (including shifts from coal- and oil-fired power plants to output at generating units that use natural gas), and from adding carbon-free electricity sources (like wind, solar, and -nuclear capacity).[5]

Figure 5

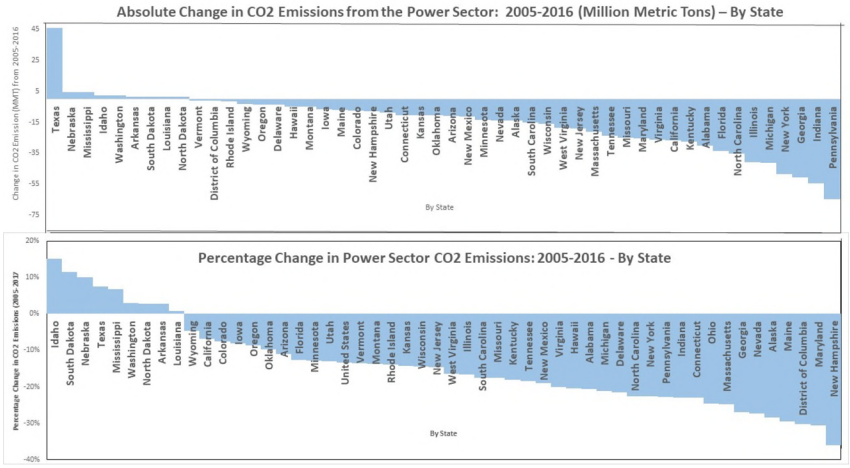


Source: EIA, "Carbon dioxide emissions from the U.S. power sector declined 28% since 2005," October 29, 2018.

[5] I note that had several financially distressed existing nuclear plants (e.g., the Ginna and Fitzpatrick nuclear units in New York, and the Quad Cities and Clinton nuclear stations in Illinois) retired in recent years in the absence of state actions to compensate those plants for their zero-carbon generation, these overall emission reductions would have been much modest.

These power-sector CO_2 emissions reductions have been coming from almost all corners of the United States. As shown in Figure 6, nearly every state experienced a reduction in CO_2 emissions from in-state power plants from 2005 through 2016. (The top section of Figure 6 shows the absolute reduction in CO_2 emissions (in tons), comparing 2016 to 2005 emission levels, while the bottom section of Figure 6 indicates the percentage change in each state's power-sector CO_2 emissions from 2005 to 2016.) Overall, the U.S. improved the carbon footprint of the electricty sector, lowering CO_2 emissions per MWh of electricity by 25 percent from 2005 to 2016; all but two states lowered their carbon intensity.[6]

Figure 6: Reduction in CO_2 Emissions from the Power Sector by State: 2005-2016



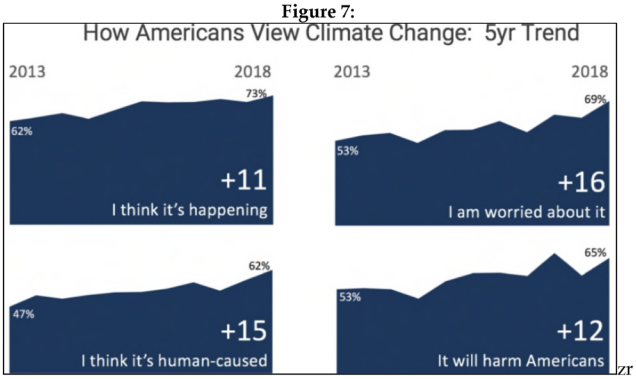
Source: EIA data on emissions by state, https://www.eia.gov/environment/emissions/state/

Many developments are occuring around the country that promise to continue these trends. For example, increasing majorities of Americans now believe that climate change is occuring, that they are worried about it, that it is caused by human activity, and that it will harm Americans.[7] (See Figure 7.)

[6] According to EIA data, all but two states improved (i.e., lowered) their carbon intensity from 2005-2016. North Dakota showed the biggest improvement, with a 43-percent reduction in CO_2 per Mwh. At the other end of all of the states was Louisiana, with a 5-percent increase in carbon intensity. Most states experienced substantial improvement.

[7] "These increases have occurred across the political spectrum….[These trends] have occurred among Democrats and Republicans (although often to different degrees). For example, the 16-point increase in the proportion of Americans who are worried about global warming is largely the result of increased worry among both moderate/conservative Democrats (+19) and conservative Republicans (+18)." Abel Gustafson, Parrish Bergquist, Anthony Leiserowitz, and Edward Malbach, "A Growing Majority of Americans Think Global Warming is Happening and are Worried," Yale Program on Climate Change Communications, February 21, 2019 (hereafter "Yale February 2019 Climate Note"), http://climatecommunication.yale.edu/publications/a-growing-majority-of-americans-think-global-warming-is-happening-and-are-worried/.

Figure 7:



Source: Yale February 2019 Climate Note

Also, many states have elected to adopt policies to introduce increasing amounts of renewable energy and energy efficiency measures: for example, 29 states, Washington, D.C., and 3 territories have adopted renewable portfolio standards, with many of these jurisdictions having recently increased their targets for renewable energy supply in future years.[8] Some states (e.g., New York, Illinois, Connecticut, New Jersey) have adopted policies intended to retain zero-carbon-emitting generation by helping to assure that these existing nuclear plants remain on line as long as they are safely operating.[9] Many states have firm GHG-emission reduction targets. Hundreds of cities and counties around the country have pledged to reduce greenhouse gas emissions from their own energy use and in their communities.[10] Major corporations have entered into long-term contracts to purchase power from renewable energy projects.[11] More and more consumers are installing rooftop solar systems on their

[8] Database of State Incentives for Renewables and Efficiency (DSIRE) website, http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2018/10/Renewable-Portfolio-Standards-2018.pdf.
[9] National Conference of State Legislatures, "State Action in Support of Nuclear Generation," January 26, 2017, http://www.ncsl.org/research/energy/state-action-in-support-of-nuclear-generation.aspx; Doug Vine, "Promising solutions for zero-emission nuclear power," Center for Climate and Energy Solutions (C2ES), October 31, 2018.
[10] According to the C2ES: "More than 350 Climate Mayors in the U.S. have adopted the Paris Agreement goals for their cities. And more than 100 U.S. cities both large and small have pledged to transition their communities to 100% clean energy. About two-thirds or more of mayors who responded to a recent survey by C2ES and the U.S. Conference of Mayors said they generate or buy renewable electricity to power city buildings or operations, buy green vehicles for municipal fleets, and have energy efficiency policies for municipal buildings. And they want to partner with the private sector do more." https://www.c2es.org/content/city-climate-policy/.
[11] As of December 14, 2018, "publicly announced contracted capacity from corporate power purchase agreements (PPAs), green power purchases, green tariffs, and outright project ownership in the United States cumulatively reached an annual high of 6.43 gigawatts (GW). Facebook, AT&T, Walmart, ExxonMobil and Microsoft lead the clean energy acceleration with the top five highest volume in deals. Facebook [has…] several deals totaling 1,849.5 megawatts (MW), while also breaking all buyer cumulative annual procurement records since deals have been tracked." "Corporate Renewable Energy Procurement Continues to Break Records in 2018," Rocky Mountain Institute, December 14, 2018, https://rmi.org/press-release/corporate-renewable-energy-procurement-continues-to-break-records-in-2018/.

buildings.[12] Around the country, the only new generating facilities planned to be added are either gas-fired or wind and solar, in large part because the costs of clean electric technologies continue to drop (and because of the expectation of many investors that there will eventually be controls on power-sector CO_2 emissions).

These trends point strongly suggest that there will be further GHG-emission reductions from the power sector in the future. Further, the trends offer the opportunity for consumers and suppliers to rely on cleaner electricity supply to provide substantial sources of energy for vehicles, industrial operations and building end uses as technologies and costs of doing so improve in the future, and, in so doing, help to further reduce GHG emissions in other parts of the economy beyond the electric sector.

But even with this past decade's substantial success in reducing CO_2 emissions from the power sector without overall adverse economic impacts to the economy or to consumers, the news is far from uniformly positive and not all groups have benefitted from these changes.

First, the effects of climate change are showing up in dramatic and costly ways around the country. The 2018 National Climate Assessment, published by the federal government at the direction of Congress, concluded that the "Nation's energy system is already affected by extreme weather events, and due to climate change, it is projected to be increasingly threatened by more frequent and longer-lasting power outages affecting critical energy infrastructure and creating fuel availability and demand imbalances. The reliability, security, and resilience of the energy system underpin virtually every sector of the U.S. economy. Cascading impacts on other critical sectors could affect economic and national security."[13] Similar conclusions were reached in 2017 by the National Academies of Sciences, Engineering and Medicine's Committee on Enhancing the Resilience of the Nation's Electric Power Transmission and Distribution System (of which I was a member).[14]

In the past few years, climate change has led to droughts, flooding, sea level rise, wildfires, ice storms, and other impacts.[15] Many of these effects have adversely impacted electric-system (and other energy) infrastructure, disrupting service to consumers and leading in many cases to much worse outcomes (such as in the case of the catastrophic 2017 and 2018 wildfires in California that were triggered by electrical equipment and which led to loss of life, homes, other property, and entire communities).

Second, GHG-emission reductions are not happening fast or deeply enough. In fact, U.S. power-sector CO_2 emissions actually increased in 2018 relative to 2017. (See Figure 8.) According to a new study by Rhodium Group of recent emissions trends, several things contributed to these increases: higher overall electricity use in 2018 compared to 2017; output at gas-fired plants making up for most of the incremental demand as well as for most of the continued reduction of output at coal-fired power plants; and continued additions of wind and solar projects.[16] Summing up these effects, Rhodium concluded

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[12] "Nearly 60 GW of total solar capacity now installed. Average annual growth rate of 59% over the last 10 years. Generates enough electricity to power more than 11.3 million homes." Solar Energy Industry Association, https://www.seia.org/solar-industry-research-data.

[13] Fourth National Climate Assessment, Chapter 4 (Energy Supply, Delivery and Demand), 2018. https://nca2018.globalchange.gov/chapter/4/.

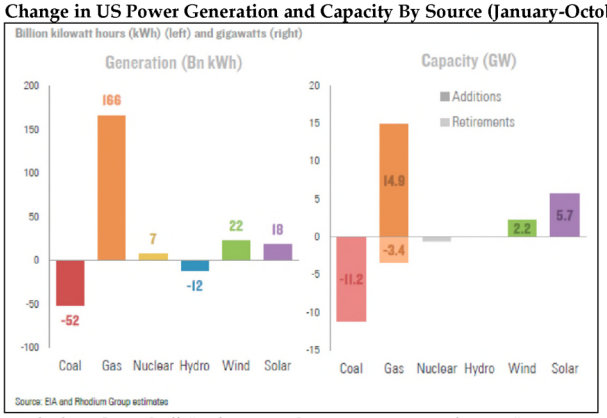
[14] National Academies of Sciences, Engineering, and Medicine, *Enhancing the Resilience of the Nation's Electric System*, The National Academies Press, 2017, https://doi.org/10.17226/24836.

[15] Fourth National Climate Assessment, 2018, https://nca2018.globalchange.gov.

[16] Rhodium Group Staff, "Preliminary US Emissions Estimates for 2018," January 8, 2019. https://rhg.com/research/preliminary-us-emissions-estimates-for-2018/.

that between "January and October, US power companies added a greater share of gas capacity than the share of retired coal capacity, and twice as much gas went online as combined wind and solar capacity additions (including distributed solar) during that period. Natural gas-fired generation increased by 166 billion kWh during the first ten months of the year. That's three times the decline in coal generation and four times the combined growth of wind and solar."

Figure 8: Change in US Power Generation and Capacity By Source (January-October 2018)



Source: Rhodium Group Staff, "Preliminary US Emissions Estimates for 2018," January 8, 2019.

Looking ahead, there is significant need for more urgent action to reduce GHG emissions to levels consistent with avoiding the worst effects of climate change. The current progress is important, in part because it demonstrates what it do-able. But recent federal government estimates of future GHG emissions from the U.S. power sector (and other sectors of the economy) do not forecast emissions reductions at rates or levels anywhere near consistent with such levels.

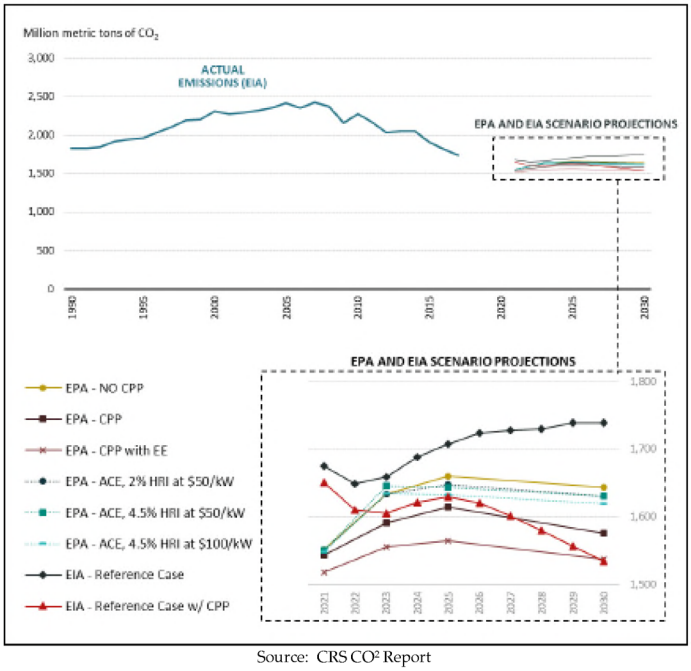
The Congressional Research Service recently summarized various carbon-emission forecasts from a several federal agencies that compare EIA's 2018 reference case (which based on current policy) with other scenario estimates from EIA and from the Environmental Protection Agency ("EPA"). These agency forecasts examine emissions trajectories under alternative assumptions about implementation of the Clean Power Plant ("CPP") versus EPA's proposed Affordable Clean Energy ("ACE") rule. None of these estimtes depict emissions outlooks that are consistent with the need for the U.S. to significantly lower carbon emissions while also increasing vehicles', buildings' and industries' reliance on clean electricity. (See Figure 9.) The recent EIA 2019 Annual Energy Outlook's reference case similarly projects power-sector emissions as being flat, at around 1.5 billion metric tons of CO^2 per year beyond 2020[17]—an outlook that is fundamentally inconsistent with avoiding the worst effects of climate change.

As part of many efforts around the U.S. to address these challenges facing the electric sector in a changing climate, the Senate Energy and Natural Resources Committee can play a critically important role in the near term to raise national ambition and support solutions related to this important issue.

[17] EIA, Annual Energy Outlook 2019, page 103 of the PPT format, https://www.eia.gov/outlooks/aeo/.

Americans' economic security, physical health, and national security depends upon further action to address climate change, and the Committee's jurisdiction over research and development activities at the Department of Energy positions it to play an important role in helping to solve the climate challenge.

Figure 9: Actual and Various Projected CO_2 Emissions from the U.S. Power Sector



Source: CRS CO^2 Report

I hope that as the Committee undertakes its efforts to shine attention on climate change and the role of the power sector in addressing it, the Committee succeeds in cultivating serious, constructive, and pragmatic discussions about clean-energy, low-carbon solutions. As the Committee focuses its spotlight on climate solutions, it will be important to avoid adopting prematurely narrow technological solution sets (such as hard-and-fast commitments to renewable-only solutions) and to create options for the many different technologies and strategies that will be needed to allow Americans to prosper in a low-carbon economy.

Thank you for affording me this opportunity to present this information to the Committee.

Bio of Susan F. Tierney, Ph.D.

I am a Senior Advisor at Analysis Group, Inc., a 850-person economic consulting firm headquartered in Boston, Massachusetts, with other U.S. offices in California, Colorado, Illinois, New York, Texas, and Washington, D.C.

I have been involved in issues related to public utilities, ratemaking and electric industry regulation, and energy and environmental economics and policy for over 25 years. During this period, I have worked on electric and gas industry issues as a utility regulator and energy/environmental policy maker, consultant, academic, and expert witness. I have been a consultant and advisor to private and publicly owned energy companies, grid operators, government agencies, large and small energy consumers, environmental organizations, foundations, Indian tribes, and other organizations on a variety of economic and policy issues in the energy sector.

Before becoming a consultant, I held several senior governmental policy positions in state and federal government, having been appointed by elected executives from both political parties. I served as the Assistant Secretary for Policy at the U.S. Department of Energy. I held senior positions in the Massachusetts state government as Secretary of Environmental Affairs; Commissioner of the Department of Public Utilities; Executive Director of the Energy Facilities Siting Council; and chair of the Board of the Massachusetts Water Resources Authority.

My Masters degree and Ph.D. in regional planning are from Cornell University. I previously taught at the University of California at Irvine and at MIT. I am a Visiting Fellow in Policy Practice at the University of Chicago's Energy Policy Institute; and a member of the advisory councils at New York University's Institute for Policy Integrity and Duke University's Nicholas School for the Environment.

I currently sit on several non-profit boards and commissions, including as: chair of ClimateWorks Foundation and of Resources for the Future; a trustee of the Barr Foundation; and a director of World Resources Institute, the Energy Foundation, and the Keystone Center. I am a member of the Committee on Modernizing the U.S. Electricity System of the National Academies of Sciences, Engineering, and Medicine; NYISO's Environmental Advisory Council. I recently chaired the U.S. Department of Energy's Electricity Advisory Committee and chaired the National Renewable Energy Laboratory's External Advisory Council, and was a member of the National Academy of Sciences committee on resiliency of the U.S. electric system. I was co-lead convening author of the Energy Supply and Use chapter of the Third National Climate Assessment, served on the Secretary of Energy's Advisory Board, and chaired the Policy Subgroup of the National Petroleum Council's study of the North American natural gas and oil resource base.

After 35 years in Boston, I moved with my husband to his home state of Colorado in 2016.

The CHAIRMAN. Thank you, Dr. Tierney.
Dr. Medlock, welcome.

STATEMENT OF DR. KENNETH B. MEDLOCK III, JAMES A. BAKER, III, AND SUSAN G. BAKER FELLOW IN ENERGY AND RESOURCE ECONOMICS, AND SENIOR DIRECTOR, CENTER FOR ENERGY STUDIES, JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY, RICE UNIVERSITY

Dr. MEDLOCK. Thank you. It's a pleasure to be here to talk about this. I agree with Susan, this is a very important topic, and I'm glad that the Committee is actually undertaking a broader discussion of these issues.

When I was approached about testifying, the title of the hearing, sort of, caught me by surprise. It was, sort of, like a big wow moment, right? Because, you know, in the discussion it was mentioned that cost, technology, emissions, to the extent that they could be addressed, via the jurisdiction in this Committee, were all raised. And one of the things that I commented about was that is a massive undertaking. But it's an incredibly important one because it runs the gamut in the electric power sector from capacity investment options to operations to grid design. It ends up getting into discussions about the future of the utility. And when you start having those kinds of conversations, it's often important to look back and think about where we've been and why we are where we are today.

Nationally, as has been indicated already, there's been significant progress made, but it's important to understand why. And I think this is a really, really important point because it highlights why some regions are different than others.

Legacy is an incredibly important word when we start talking about transitions in any energy space, much less the electric sector alone. Coal-fired generation capacity in this country is aging. And we are actually at a point now, given the last time there was a major expansion of coal-fired generation capacity which was in the late '70s, early '80s where we're nearing the 40th birthday of a big chunk of capacity in this country.

And that presents a very serendipitous situation, namely in particular with low cost natural gas but declining costs of renewables, it means that generators and utilities have a choice, they can retire and replace or they can upgrade and retrofit. And economically, that's a real easy decision to make right now.

So it's important to understand what's driving the change. It's certainly got elements of policy in it at a national level, but it also has a tremendous amount to do with economic realities on the ground.

An interesting point about all this is that what we see at the national level, some of the trends that have already been highlighted, has really been driven by what's occurring at a local level. State renewable portfolio standards have certainly played a role in accelerating the adoption of renewables but it goes beyond just states. You also have in certain states, municipal renewable portfolio standards.

So, you know, there's an old saying, "Politics are local." And I think you're seeing that play out with regard to power generation,

choices that are being made across the country in different municipalities. The power of revealed consumer preferences also playing a role in states where you do have things like retail competition. For example, you're seeing individuals prefer to contract for long-term supplies of green energy, and what that actually does is it transmits a signal all the way through to the wholesale level that actually drives contracting and ultimately construction for things like wind power which you've seen a tremendous amount of investment in the State of Texas, where I'm from.

So, all of these things are really important to recognize, but it's also important to recognize that it goes beyond just investments in generation capacity. Grid design is also incredibly important. Infrastructure related to the ability to move power from one state to the next is incredibly important because, for example, and this is highlighted in my written testimony. The State of New York is actually seeing a precipitous decline in the use of coal for power generation but most of that has actually been facilitated by an increase in imports into the state. And so, that's where you have to, sort of, look farther, sort of, back upstream and figure out where that's coming from to understand what the ultimate impact is. But the more grid-connected different regions are, the more options they're presented with when they start to address the issues that we're all confronted with.

Various incentives have been incredibly important. And that's not just true in the United States because you look around the world, actually look at Europe. You look at, you mentioned the address of Dr. Birol last week, thinking about the different policy options that are confronted, are confronting countries like China, India, other countries, in—where there are massive populations, 3.3 billion people, collectively, trying to grow and achieve the levels of economic prowess that we enjoy in the West. Those options, those policy options are going to be incredibly important in shaping their future, but they also need to see some direction. And this is actually where some of the things that can come out of this Committee can be very beneficial because leading by example is often the best way to lead. But one of the things that we really need to think seriously about is basic R&D because research and development really does pave the way of the future.

I like to say that the next great innovation is in the mind of a four-year-old somewhere playing with Legos. We don't know what it's going to be, but we need to actually create pathways so that those innovations can make their way to the future and pave the way to a brighter future for us all.

Thank you.

[The prepared statement of Dr. Medlock follows:]

JAMES A. BAKER III
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Testimony of

Kenneth B. Medlock III
James A. Baker, III, and Susan G. Baker Fellow in Energy and Resource Economics, and
Senior Director, Center for Energy Studies
James A. Baker III Institute for Public Policy
Rice University

to the

Senate Committee on Energy and Natural Resources
Washington, D.C.

Hearing on

The Electricity Sector in a Changing Climate

March 5, 2019

The broad array of topics that can be covered under the umbrella of the "The Electricity Sector in a Changing Climate" is massive, and the subject matter in its entirety is certainly timely. Covering topics related to infrastructure, costs and emissions runs the gamut from capacity investment to grid design to system/facility operations. Each is quite different but interrelated. Some understanding of this complexity can be had by examination of the history of how and why

electric power grids developed in the first place, and how they have evolved since.[1] The point that grids developed to balance loads across regions and increase reliability of service in disparate utility regions is an important one, and it is related to more general conversations about the role of trade in enhancing energy security. Indeed, the lessons of the past have profound bearing as our energy systems, policy-makers and system operators prepare for the future.

Given the breadth of issues that can be explored, this exposition will focus on what has transpired since 1990 – with regard to observed trends in electricity generation by source – and the role of infrastructure. This will highlight how important local/regional/state policy has been in re-shaping the reality of electric power markets. The importance of this cannot be overstated as historically it has often been subsumed into national-level conversations about "the future of the utility", power sector emissions, and energy security.

More generally, the evolution of the electric power sector falls under the umbrella of "energy transitions" discussions. Thus, it should be recognized that two of the most impactful developments over the last 20 years have been (i) the shale revolution in the US and (ii) demand growth in developing Asia. Importantly, neither of these instigators of change is retiring. Rather, the full impact of each is still unfolding and will have ripple effects for domestic and international energy markets for years to come. This is an important point as it has direct bearing on developments in the US, especially with regard to (i), which has made natural gas a relatively abundant, low-cost option for reducing dependence on coal in power generation.

Some Historical Perspective

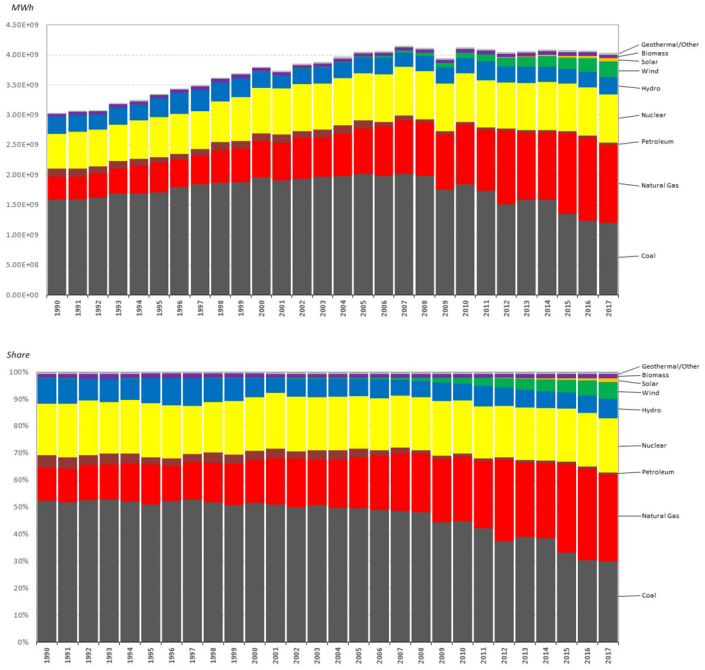
In the last 10 years, the US power sector has undergone a significant transition. As indicated in Figure 1, the years prior to 2007/8 saw a fairly consistent fuel mix in the power sector, with coal capturing around 50% of the market and nuclear around 19%. During the same period, natural gas share increased from just over 12% of the market to just over 21%, representing the largest increase, while other sources saw either declining (petroleum and other gases and hydro) or flat market but small shares (biomass, geothermal, wind and solar). Since 2007/8, a radically different reality has unfolded. To begin, both the use of coal and coal's market share have declined precipitously while the absolute quantities, as well as shares, of natural gas, wind and solar have all increased.

While the shifts in power generation witnessed across the US over the last decade are noteworthy, it is important to note that the realities are different in different regions. In fact, this can begin to shine a light on the drivers of the changes witnessed at the national level. For example, renewable portfolio standards are policy mechanisms that remove offtake risk for renewable sources of generation – effectively guaranteeing purchase of produced electricity.

[1] At the Baker Institute, we are currently involved in research that is more fully exploring this important yet underappreciated aspect of the ongoing evolution in electric power markets. This research is ongoing and will be published during the summer of 2019.

Such policies have been very effective at driving greater penetration of renewables, and newly announced more aggressive policies will likely continue this trend.[2] But every state is different, with some RPS being established in distinct, localized utility areas, meaning local preferences can drive what is observed at an aggregate level.[3]

Figure 1 – U.S. Electricity Generation by Source (Quantity and Share), 1990-2017

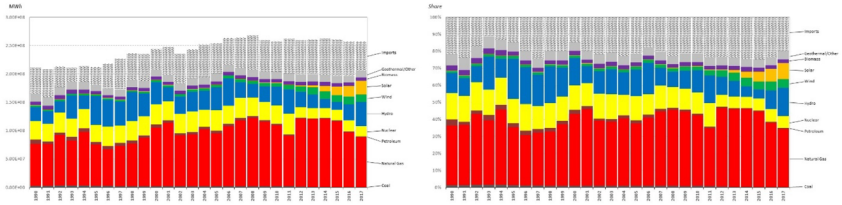


Source: Data from US Energy Information Administration

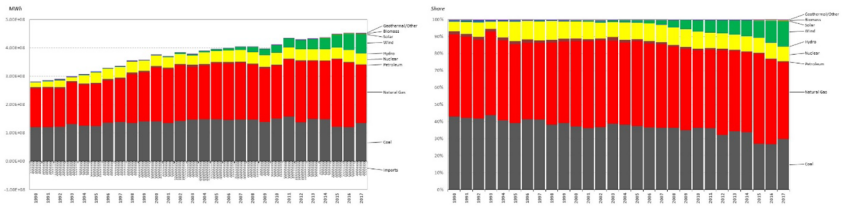
[2] See https://www.eia.gov/todayinenergy/detail.php?id=38492 for some analysis by the EIA on this.
[3] See http://programs.dsireusa.org/system/program?type=38& for a comprehensive listing of RPS.

Figure 2 – Electricity Generation by Source by Select Region, 1990-2017

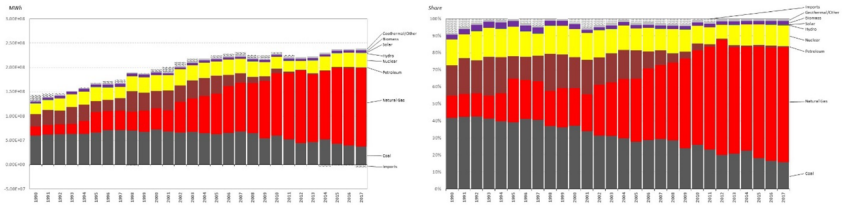
California



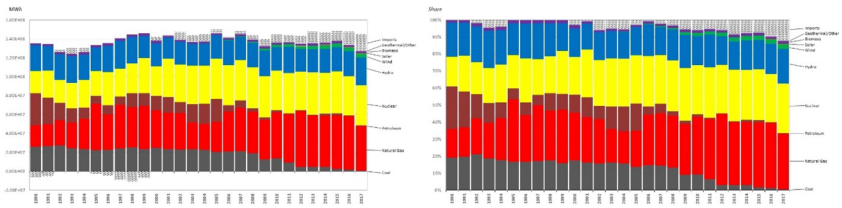
Texas



Florida



New York



Source: Data from US Energy Information Administration

Consider the cases of California, Texas, Florida and New York (see Figure 2). Each state has seen a shift away from coal, but at different rates and for different reasons. This heterogeneity

cannot be ignored. For example, California's coal-fired generation has been minimal since 1990, and it primarily resided in combined heat and power applications. In addition, very aggressive energy efficiency programs and significant imports have allowed in-state generation to remain relatively flat while wind and solar take increasing shares. Of course, the source of imported power generation is critical when assessing the net impact of the observed trends in California on total emissions. This is where policy in California has been proactive, with AB32 attempting to address emissions from all sources of electricity sold in the state.[4] The only caveat is that sources of power generation outside the state are fungible, so *contracted* power and *delivered* power need not be from the same source. Nevertheless, the approach taken in California is forward-looking insomuch as it is considering sources of imports as well as in-state generation.

Texas has experienced a different path than California. Texas has witnessed a slight decline in coal use, while natural gas and wind have risen significantly. In terms of share, coal has declined more significantly as natural gas and wind have captured the margin of growth from the increase in total power generation. Something that sets Texas apart from other states is the fact that the majority of the state is in ERCOT, which is largely disconnected from neighboring reliability council regions. So, the ability to trade with neighboring states is limited.

A point worth expounding here (and raised in previous testimony[5]) is the interdependent role of regulatory environment and infrastructure that is highlighted by the Texas experience. Wholesale and retail competition were introduced in Texas with Senate Bill 7. Competitive pressures in the retail power sector subsequently forced firms to differentiate themselves by offering specific technologies and energy services. This has, in turn, benefitted wind generation. To be clear, wind capacity investments have benefitted greatly from overt policy support – such as municipal utility RPS as well as investment tax credits and production tax credits – but they have also been propelled by consumer demands that have been made explicit through active marketing of renewable energy by retail providers. As wind capacity investments have grown, massive transmission infrastructure investments have also been required to connect resources to consumers, the cost of which is ultimately passed through to consumer bills. Similarly, some retail energy service providers have expanded their offerings into the introduction of smart technologies and distributed generation assets, which represent infrastructure investments at the commercial and residential levels. Thus, the regulatory and market environment along with the expansion of infrastructure have been critical for unlocking wind resource opportunities and pushing distributed generation and energy efficiency (albeit to a lesser extent) in Texas.[6]

Florida has also seen a significant decline in the use of coal in power generation. Moreover, while Florida used to see a lot of in-state power generation from petroleum, that is no longer the

[4] See https://www.arb.ca.gov/cc/ab32/ab32.htm for more information.
[5] See Senate Energy and Natural Resources (SENR) testimony on Energy Infrastructure from February 8, 2019. This is available at the SENR website or https://www.bakerinstitute.org/research/medlock-testifies-energy-hearing/.
[6] See "Electricity Reform and Retail Pricing in Texas" (June 2017) by Peter Hartley, Kenneth Medlock, and Olivera Jankovska, available online at https://www.bakerinstitute.org/research/north-american-energy/

case. Natural gas use has grown substantially, and accounts for virtually all of the displacement of coal and petroleum in the power sector. To compound the role that natural gas has played in Florida, power generation has grown (just as in Texas) at an appreciable clip over the last couple of decades, meaning natural gas is not only displacing other sources of generation, it is also capturing new margins of growth. Notably, renewables still only account for a very small fraction of generation in Florida.

New York represents yet another different circumstance. New York has seen its use of coal and petroleum decline, just as in other states. The observed increase in natural gas use in New York effectively accounts for all of the decline in petroleum use. Wind and solar have increased slightly, but the increase in wind and solar only account for about 17% of the decline in coal use from its apex, while imported electricity accounts for about 64%. Hence, the fact that New York is grid-connected to other regions (including Canada) has allowed it to reduce its in-state generation carbon footprint. However, as noted above for the case of California, the source of the imported generation is important when considering the net implication for emissions.

We could continue in this manner to expound on the differences across all states, but the point should now be apparent. Differences in political and regulatory incentives, differences in market structures, differences in economic realities, and differences in resource opportunities all vary across states and regions. As such, the approaches to power sector management and operation have varied. The common threads across all locales are (i) the declining costs of renewables that have altered the competitive landscape and aided more rapid adoption, (ii) the low cost of natural gas relative to other fuel choices, and (iii) the importance of infrastructure investments to new generation technologies at scale and connect them to consumers in an integrated manner, the latter of which is especially vital for fluid integration of non-dispatchable resources such as wind and solar.

An Important Instigator of Change – The Role of Legacy

Serendipity has afforded a significant amount of what has been observed across states/regions. At the center of this is the role the legacy plays across the energy industry, much less the electric power sector. To begin, the last major build-out of coal-fired generation capacity in the US was in the late-1970s to early-1980s. This was driven by energy security concerns in the post-1970 oil-shock world as well as concerns about declining natural gas resources. Nevertheless, as this capacity was added to the US generation fleet, a high dependence on coal for power generation was effectively locked-in for the next three to four decades.

Fast-forward to 2008. An aging coal fleet begins to see its competitive advantage compromised with the shale revolution. Moreover, significant investments in natural gas combined cycle generation capacity in the early 2000s provided a nascent source of demand for low cost natural gas to begin to displace coal. We now sit at the 40th birthday of a large fraction of the nation's coal capacity. As such, power producers have an economic decision to make about the existing

coal fleet – retire and replace or upgrade and retrofit. As long as natural gas remains low cost and renewables continue to see cost improvements, this decision is relatively easy – retire and replace. Moreover, a transition away from coal can happen fairly rapidly because of the age (legacy) of the coal fleet. Advances in storage technologies have the potential to exacerbate this impact, especially if they can effectively regulate the delivery of power from non-dispatchable renewable resources.

The pace of retirements of coal capacity will vary by region, even if policy were not different. This is because the age of coal capacities varies by region, and the availability of natural gas at low cost (which can be hindered by inadequate pipeline capacity – more on this below) coupled with natural gas-fired generation capacity also varies by region. Layer over this the different approaches to power sector regulation and market structure that exist across states, and the heterogeneity of possible outcomes across regions expands. But this simply highlights other important instigators of change that have been referenced above – the roles of policy and regulation.

Of course, as generation capacity is turned over, certain infrastructures may become obsolete – such as rail lines and coal mines – but other infrastructures are needed to facilitate a smooth turnover. In the current US market, this includes new power plants, new pipelines, and new power lines and expanded grids, all of which will establish a new legacy for US power markets that is reliable and has lower emissions intensity.

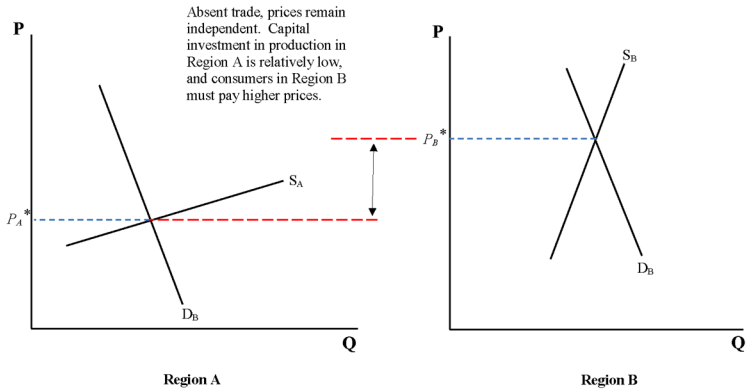
The Importance of Infrastructure

Infrastructure plays a very important role in the commercialization of new energy technologies and resources. In fact, the deployment mechanism for new technology is capital investment in infrastructure. Absent such investments, which are often required at considerable scale, new technology remains "on the bench" seeking answers or incentives for deployment. In sum, infrastructure is vital for well-functioning markets. It plays a critical role in connecting producers and consumers, and if deep, well-functioning markets are desired, then sufficient infrastructure is critical. For investments to develop new supplies to happen, infrastructure that facilitates market access is vital. Accordingly, the absence of sufficient infrastructure can disrupt investment and have bearing on whether there is adequate and reliable supply available to end-users.

Infrastructure investments need not only be in supply, generation and delivery. Investments in storage technologies/capacities and energy efficiency technologies are also infrastructures that have bearing on the delivery of energy services to consumers. For example, energy efficiency can be enhanced through infrastructure investments in "smart" technologies that convey real time pricing data to consumers thus allowing them to adjust consumption patterns in response. When this occurs, it can reduce overall electric system load and allow existing generation resources to operate in ranges that maximize system redundancy and reliability.

Trade between regions via power lines enhances market function and adds elements of reliability and security of supply for consumers. A simple illustration rooted in trade theory can demonstrate this point.[7] Consider two regions that could be connected by infrastructure to facilitate trade, but initially are not. In Region A, there is an abundance of available supply relative to demand. In Region B, there is less supply available relative to demand. As indicated in Figure 3, absent the ability to trade, prices across the regions will be set independently, and markets will balance at the indicated prices, P_A^* and P_B^*.

Figure 3 – Two regions: No infrastructure and no trade



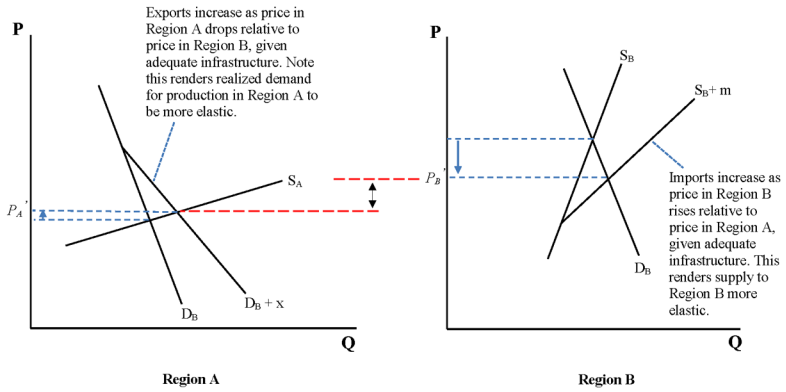
However, as indicated in Figure 4, if we introduce the physical ability to arbitrage the price differences between Regions A and B, the prices in each region will be set simultaneously, rather than independently, and the markets will clear at P_A' and P_B', where the difference between prices reflects the cost of transport between the two regions. Notably, when infrastructure does not exist, the effective cost of trade (shadow cost) is infinite, so prices in the two regions can float through a very wide range.

The same thing is true if infrastructure is limited and insufficient. If trade via new or expanded infrastructure is possible, it increases the likelihood that investment will flow into Region A to facilitate more production. Lower prices through trade also incentivize investments in Region B that accommodate greater demands. The exact movements of prices in each region will depend

[7] This point is expounded in previous SENR testimony on Energy Infrastructure from February 8, 2019. This is available at the SENR website or https://www.bakerinstitute.org/research/medlock-testifies-energy-hearing/. We re-introduce this concept here because it is very relevant to the broader discussion of "The Electricity Sector in Changing Climate."

on the relative elasticities (price responsiveness) of supply and demand in each region, which will also determine the amount of trade that occurs (and infrastructure that is required).

Figure 4 – Two regions: Adequate infrastructure and trade

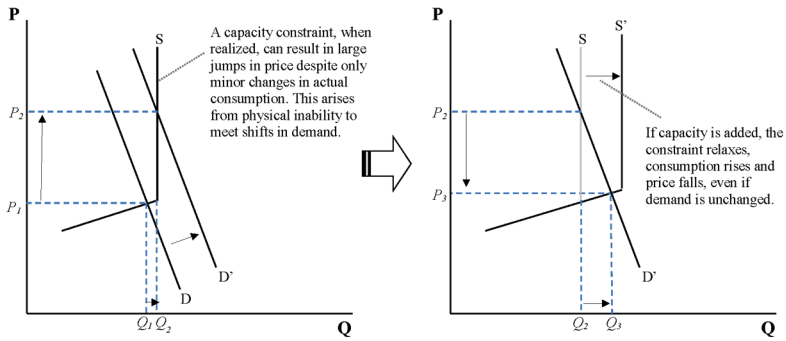


To stop here does not fully explain the value of infrastructure for price formation and supply availability across the two regions. Notice, in Figure 4, how the elasticities (slopes) of supply in Region B and demand in Region A are affected when there are no impediments to trade. If we allow demand to vary through time – daily, weekly, seasonally, etc. – as is generally the case for electricity, price volatility is dampened and supply availability is enhanced, all else equal, when trade is allowed. This is a very important point as one considers wider adoption of renewable energy sources, especially since variability in the delivery of electricity can be generated by natural factors – wind blowing and sun shining. Hence, capturing geographic differences in the availability of non-dispatchable renewable resources as well as dispatchable thermal resources can provide a very important balancing effect for power markets by allowing a seamless substitution of generation resources. In fact, wholesale electric power markets have been doing this for years, but the introduction of new variable generation infrastructures have the potential to be disruptive to the status quo while adding another element of diversification to the overall grid. Maximizing the benefits requires a grid that can overcome regional imbalances smoothly via trade.

When infrastructure is insufficient, short term movements in supply and demand can result in significant price dislocations. Consider, for example, Figure 5. Here, we see a region that initially has sufficient capacity to deliver energy for a given demand schedule, then a shift in demand results in existing infrastructure being insufficient (see Step 1 in Figure 5). The result of

the realization of the deliverability constraint[8] is a significant increase in price even though actual consumption may not rise very much. Notably, if electricity demand swings on a daily, weekly or monthly basis this can result in excessive price volatility as the constraint is realized and relaxed frequently.

Figure 5 – The Role of Capacity Constraints in Price Formation



If we add delivery capability to the market, the constraint is relaxed, even at the higher level of demand (see Step 2 in Figure 3). In both cases (Steps 1 and 2 depicted in Figure 5), the market clears where available supply equals demand, resulting in a market clearing price and quantity. But, in the case where the deliverability (supply) constraint is relaxed, price is lower, greater consumption is facilitated and price volatility is dampened.

Closing remarks

There are some new and emerging developments that have the potential to be very transformative. As one example, electrification of the vehicle fleet poses infrastructure challenges with regard to power generation and transmission capacity and recharging outlets. In the near term, the existing generating fleet is likely sufficient to meet almost any expectation of electricity demand growth associated with electric vehicle (EV) adoption. Current recharging infrastructure is also likely sufficient for low levels of EV penetration, but as more consumers drive EVs, scale effects begin to take hold and more recharging infrastructure will be required. The location of re-charging stations also becomes relevant for long distance travel. As EV

[8] "Deliverability constraints" refer to constraints on access to capacity, which can result if physical capacity is short or if capacity is rendered unavailable through other means. In any case, the result is an increase in price.

penetration increases, the resulting requirements for new electric generation capacity – regardless of fuel type – will be significant.[9] And, the sources of power generation required will be diverse – ranging from renewable energy sources to natural gas. Accordingly, this highlights the importance of infrastructure – additional power generation and distribution capacity as well as new natural gas pipeline infrastructures and supplies.

Politics are local. Addressing broad goals of emissions reduction while seeking reliable electricity supply to consumers must recognize this. If top-down approaches are taken, the risk of disenfranchising particular segments of the population can be large, especially if the approach does not recognize local comparative advantages. Indeed, this can ultimately derail the policy approach, as well-intentioned as it may be. Thus, approaches aimed at creating opportunities that leverage local comparative advantages should be explored. If one can design policy that is flexible, it may allow a wide array of regional approaches that accomplish a broad goal. But such policy approaches are likely to be less prescriptive and more incentive-based, which raises the specter of using price signals – such as taxes, tax credits, etc. – to drive future investments.

[9] See, for example, "Energy Market Consequences of Emerging Renewable Energy and Carbon Dioxide Abatement Policies in the United States," by Peter Hartley and Kenneth B Medlock III (Sept 2010), available at https://www.bakerinstitute.org/research/energy-market-consequences-of-emerging-renewable-energy-and-carbon-dioxide-abatement-policies-in-the/.

The CHAIRMAN. Thank you, Dr. Medlock.
Ms. Jacobson, welcome.

STATEMENT OF LISA JACOBSON, PRESIDENT, BUSINESS COUNCIL FOR SUSTAINABLE ENERGY

Ms. JACOBSON. Yes, thank you very much.

Chairman Murkowski, Ranking Member Manchin and members of the Committee, again, I want to commend you on putting forward this very important hearing.

I'm here representing the Business Council for Sustainable Energy (Council). The Council is a coalition of companies and trade associations in the U.S. energy sector with a specific focus on energy efficiency, natural gas and renewable energy. The BCSE also has a small business arm, the Clean Energy Business Network and together the Business Council and the Clean Energy Business Network represent a broad range of the clean energy economy from Fortune 100 companies to small businesses working in all 50 states.

On behalf of the Council, I'd like to express our appreciation for the longstanding, bipartisan support and approach and the accomplishments of this Committee. Looking back, the 2005 and 2007 energy bills and the strong, sustained and bipartisan support for research, development and deployment initiatives at the Department of Energy, have helped shape the current energy landscape.

My testimony will refer to the findings of the 2019 Sustainable Energy in America Fact Book which was released last month by the Council and Bloomberg New Energy Finance.

In its seventh year, the 2019 Fact Book provides up-to-date facts on the U.S. energy landscape. It is not a forecast and it does not advocate for policies.

Based on Fact Book data, I would like to highlight four main points: the U.S. electricity sector is transforming and is utilizing a diverse portfolio of resources; the U.S. electricity sector is decarbonizing due to increased investment in energy efficiency, natural gas and renewable energy; the U.S. electricity sector has low cost and is enhancing our U.S. competitiveness. In 2018 while greenhouse gas emissions rose in all sectors of the economy, the power sector's carbon intensity continued to decline due to the low and zero carbon resources being used to generate power and investments in energy efficiency. It was a 2.5 percent decline in carbon intensity. The electricity sector is changing in other ways as well both in terms of technology integration, digitization, decentralization and its inner connection with buildings and transportation. Further, grid-connected buildings and vehicles are responding to electricity system needs providing new sources of system flexibility. Finally, the sector is also being impacted by natural disasters and it is facing the threat of cyberattacks.

Though I am, you know, kind of, closing the panel here, I will reiterate some important facts about the changing electricity sector that some of my panelists have said before.

First, natural gas accounts for 35 percent of electricity generation in the country. That is up 25 percent over a five-year period.

Renewable energy at the end of 2018 accounts for 18 percent of U.S. generation. This is nearly on par with the nation's nuclear fleet.

U.S. spending on energy efficiency from utilities, energy savings performance contracts, and property assessed clean energy programs climbed to a record level of $15 billion at the end of 2017. That's the most recent data we have.

On the consumer side, they devoted a record low share of their household spending in 2018 toward electricity. And these records started about 1960.

And the energy efficiency, natural gas and renewable energy sectors support over three million jobs across the country. New data on energy sector jobs will be available tomorrow. So, I encourage everybody to look at that, looking for changes in that dataset.

Further, corporations are driving change in the energy sector. Companies in many segments of the economy contracted record volumes of renewable power through direct contracts amounting to 8.6 gigawatts of capacity in 2018 alone, and this is being driven increasingly by economic factors including low renewable power prices and the ability to lock in predictable electricity prices over a period of time.

An important area of focus for this Committee is research, development and deployment (RD&D) programs at the Department of Energy. A range of clean energy and energy efficiency technologies have benefited from the full spectrum of federal RD&D support in many cases in partnership with the private sector. This includes early stage programs like ARPA-E as well as applied RD&D programs. Specific examples include initiatives to lower solar soft cost, the longstanding public-private partnership that led to shale gas production and energy efficiency technologies such as LED lighting.

In addition, the BCSE appreciates the Committee's support for modernizing the U.S. electricity system. This includes grid infrastructure as well as policies that seek to streamline and increase the efficiency of permitting and siting procedures.

The Council looks forward to continuing to work with this Committee as it moves forward on policy solutions. And again, thank you for holding this hearing today.

[The prepared statement of Ms. Jacobson follows:]

Testimony of

Lisa Jacobson, President
Business Council for Sustainable Energy

United States Senate
Committee on Energy and Natural Resources

Hearing to Examine the Electricity Sector in a Changing Climate
March 5, 2019

Chairman Murkowski, Ranking Member Manchin, and Members of the Committee, thank you for the opportunity to testify and to share the Business Council for Sustainable Energy's views on electricity sector dynamics in a changing climate.

My name is Lisa Jacobson, and I serve as the President of the Business Council for Sustainable Energy, or BCSE. On behalf of the Council, I would like to express our appreciation for the longstanding work of the Senate Committee on Energy and Natural Resources. We commend the Committee for its accomplishments in the 115th Congress and look forward to working with its members as it seeks to address pressing federal policy issues impacting the U.S. energy sector in the areas of resilient infrastructure, grid modernization, cyber security, energy efficiency and streamlining the siting and permitting process. The Committee's bipartisan approach is also to be commended, as that is key to enacting durable and predictable policies that will spur energy sector investment.

BCSE is a coalition of companies and trade associations representing the energy efficiency, natural gas and renewable energy sectors. Founded in 1992, the Council advocates for policies that expand the use of commercially-available clean energy technologies, products and services. Its membership includes project developers, industrial manufacturers, equipment and technology providers, independent electric power producers, investor-owned utilities, public power and energy and environmental service providers.

BCSE is pleased to now also have an independent initiative under its banner, the Clean Energy Business Network (CEBN). CEBN represents small- and medium-size businesses providing clean energy technologies and services.

Together, BCSE and CEBN represent a broad range of the clean energy economy, from Fortune 200 companies to small businesses working in all 50 states and over 350 Congressional districts. On a national basis, the energy efficiency, natural gas and renewable energy sectors support over 3 million U.S. jobs.

BCSE and CEBN members have a wide range of energy policy interests. As a broad-based coalition of businesses and trade associations, not all BCSE and CEBN members take a position on or endorse the views offered in this testimony.

The Council believes it is critical that Congress formulate and enact stable, long-term energy policy frameworks that leverage and align with state and local policies, as well as the private sector, to support investment and job creation. The 2005 Energy Policy Act and the 2007 Energy Independence and Security Act contained numerous provisions that have helped to shape the energy landscape of today. We look forward to working with this Committee to enact bipartisan legislation that will provide policy direction to guide investment over the next decade and beyond.

In my testimony today, I will focus on several areas:

- The rapid changes that have occurred in the U.S. electricity sector;
- The factors that have contributed to these changes;
- And, understanding that this Committee does not have jurisdiction on emissions policy, what the impact of these changes have been on U.S. electricity sector emissions over time; and
- Finally, I will address several federal energy policies should be considered to support continued investment and emission reductions in the electricity sector, as well as the U.S. economy overall.

The testimony incorporates several of the findings of the 2019 Sustainable Energy in America Factbook,[1] which was released on February 13, 2019, by the Business Council for Sustainable Energy and BloombergNEF. The 2019 Factbook is the seventh edition of the report and provides up to date, annual national information on key trends in the U.S. energy sector. The 2019 Factbook includes a comprehensive overview section as well as detailed charts, graphs and sources for information. It is developed each year to serve as a reference guide of leading energy statistics for use by policymakers and other stakeholders.

The U.S. Electricity Sector is in the Midst of a Rapid and Structural Transformation

Energy efficiency, natural gas and renewable energy are the growth areas of the U.S. electricity sector, delivering affordable, safe and reliable power to homes and businesses. Further, investment in these sectors – combined with the deployment of a range of technologies such as energy storage, combined heat and power, and fuel cells, along with demand response, automation and digital applications – is decarbonizing the power sector, keeping electricity costs low and creating jobs.

Carbon capture, utilization and storage can also play a role, especially with new policies like the extended and expanded 45Q tax credit in place.[2]

The electricity sector is changing in other ways as well – both in terms of technology integration and its interconnection with buildings and transportation. Decentralized systems are emerging, and multiple technologies can be integrated to provide a balanced and flexible system. Further,

[1] Business Council for Sustainable Energy, *2019 Sustainable Energy in America Factbook*, available at: http://www.bcse.org/factbook/.
[2] *See*, https://www.catf.us/2019/02/ccs-reduce-49-million-tonnes-co2-emissions/.

grid-connected buildings and vehicles are responding to electricity system needs, providing new sources of system flexibility.

Just as the sector is getting more decentralized, it is also being impacted by natural disasters and is facing the threat of cyber attacks. As such, the sector is looking to become more resilient, but the process is ad hoc and slow. In terms of physical resilience, there are more technology options available to fortify centralized and distributed energy systems, including advanced microgrids, bi-directional inverters and more responsive substation operations. In some cases, utilities can address resilience through their own expenditures, but in other cases private equity and third-party financing, as well as various energy-as-a-service models offer public-private partnership opportunities for communities and facilities looking to become more resilient.

From the cyber security perspective, there are important efforts underway. This work must continue, and this Committee's role is critical.

Statistics from the 2019 edition of the Sustainable Energy in America Factbook recently released by BCSE and BloombergNEF document several noteworthy overarching electricity sector trends:

The U.S. electricity generation mix is changing rapidly:

- Natural gas accounts for 35 percent of electricity generation, making it the number one source of U.S. electric power, up 25 percent over a five year period;
- Renewable energy generation accounts for 18 percent of U.S. electricity generation, nearly on par with the nation's nuclear fleet;
- Coal generation has declined, ending 2018 at 27 percent of the power mix; and
- Looking back over the past twenty-five years, natural gas and renewable energy represent over 94 percent of U.S. electric capacity additions, pointing to a structural change in the power generation mix.

Energy efficiency investment has reached new heights:

- Total U.S. spending on energy efficiency through formal frameworks – such as utilities, Energy Savings Performance Contracts (ESPCs) and Property Assessed Clean Energy Programs (PACE) – climbed to a record level of $15 billion in 2017 (the most recent year for which data is available).

Electricity prices are low for households and businesses:

- Consumers devoted a smaller share of their spending in 2018 towards electricity than at any time ever recorded, and the total share of household expenses dedicated to energy costs overall also hovered near an all-time low;
- The U.S. remains competitive globally for energy-intensive industries thanks to low industrial power prices;

- Natural gas prices have fallen dramatically over the last decade: industrial prices have fallen 59 percent; commercial gas prices have declined 37 percent and residential prices have declined 21 percent. In 2018, the average price was $3.20/MMBtu.
- Prices for wind and solar Power Purchase Agreements (PPAs) have also fallen dramatically as the levelized costs decline.

Energy efficiency, natural gas and renewable energy provide U.S. jobs:

- The renewable energy, energy efficiency and natural gas sectors supported over 3 million U.S. jobs in 2017.[3]

The Factbook also outlines the growing contributions of corporations and states in driving change in the energy sector.

The business community stepped up to drive demand:

- Retailers, major technology firms, and even a major oil company contracted record volumes of renewable power through direct contracts, amounting to 8.6. gigawatts of capacity in 2018. This is being driven increasingly by economic factors, including low renewable power prices and the ability to lock in predictable electricity prices over a period of time.
- Companies pledged to double energy productivity or to green their vehicle fleets, with electric, fuel cell and renewable natural gas powered vehicles.

States continued to engage in clean energy policymaking:

- California promised to achieve 100 percent renewables by 2045 while other states including Nevada, New Jersey and New York adopted new policies on renewables, efficiency, and battery deployment pledges. Florida agreed to allow third-party PV installers to operate in the state.

Contributions to the Changing U.S. Electricity Sector

The market dynamism in the electricity sector is partly credited to policy frameworks – at the federal, regional, state and local levels – combined with the new wave of activity by corporations in terms of electricity sector investment, renewable energy procurement and energy efficiency spending.

At the federal level, there are numerous examples of policies that have been implemented over the past ten to twenty years that have contributed to the changing electricity sector.

[3] The 2019 U.S. Energy and Employment Report will be released on March 6, 2019 by National Association of State Energy Officials (NASEO), the Energy Futures Initiative (EFI).

Examples include:

- energy efficiency standards and investments;
- tax policy;
- research, development and deployment initiatives at the Department of Energy;
- federal government leadership programs;
- air quality initiatives and public-private partnerships in the areas of clean energy technology deployment and emission reductions at the Environmental Protection Agency; and
- energy use and emissions reporting initiatives.

However, it is important to note that not all available clean energy technologies have benefitted from these policy levers, and more can and should be done to enable an opportunity for all technologies to compete.

Looking forward, policy frameworks are most effective when they focus on desired outcomes, and enable the full portfolio of diverse power generation technologies to participate. Further, policy frameworks should leverage private sector activity and create sustainable market-signals for investment. As stated in the report *Energy 2020, A Vision for America's Energy Future,*[4] the federal government can help remove roadblocks due to outdated approaches and provide strong support and funding levels for research, development and deployment.

Federal policy should not be considered in isolation. State, regional and local policies – and private sector activity – are critical to determining deployment trends and electricity costs. As the recent Breakthrough Energy report, *Advancing the Landscape of Clean Energy Innovation*, states:

> "Successful clean energy innovation on a large scale in the U.S. requires alignment of key players, policies and programs among the private sector, federal government and state and local governments."[5]

This is due in large part to the significant role that cities, states and regions have in determining power sector policies, which impact electricity generation, distribution and efficiency policies. And, with the increasing interest in companies, communities and other energy end users in having more control over their energy choices, federal decisionmakers should be mindful of these trends and seek to leverage this capital when considering policy options.

Electricity Sector Emissions Trends

The power sector has reduced its carbon emissions by over 25 percent in the past decade as it has expanded its use of natural gas and renewable energy, reduced its coal generation and benefitted

[4] Senator Lisa Murkowski, Energy 2020: A Vision for America's Energy Future, 2013. https://www.energy.senate.gov/public/index.cfm/files/serve?File_id=C691A024-1004-4D49-8DE9-A976CE0D2BF3.
[5] Breakthrough Energy, Advancing the Landscape of Clean Energy Innovation, February 2019. http://www.b-t.energy/reports/advancing-the-landscape/.

from sustained investments in energy efficiency. However, in 2018, power plants produced 3.3 percent more electricity. Thanks to a cleaner generation mix and improved energy efficiency, power sector emissions grew at a much more modest pace, 0.6 percent year-on-year. This resulted in the continuing decline in the carbon-intensity of the electricity sector.

It is interesting to contrast this with the emissions trends in other sectors of the U.S. economy and to consider why those emissions increased. While one year of data is insufficient to establish a trend, it is important to consider the possible causes for these increases in 2018. This is important as the power sector and the U.S. economy as a whole need to make significantly deeper emission reductions to meet the levels recommended by the scientific community to avoid the worst impacts of climate change.

A Deeper Dive into 2018 Emissions: Economic growth, along with extreme weather, pushed energy demand to an all-time high

Total U.S. greenhouse gas emissions rose for the first time in several years in 2018, increasing by 2.5 percent as overall energy demand increased in buildings and industrial sectors, and to a lesser extent, power and transport. Total gross greenhouse gas emissions now sit at roughly 10 percent below 2005 levels.

The U.S. economy in 2018 grew at its fastest pace in five years, posting an annualized GDP expansion rate of 2.9 percent. For the first time in several years, energy consumption grew at a faster clip than GDP, rising 3.3 percent over the same time period.

Seasonal factors played an important role, as extreme weather boosted demand for both heating and cooling in the buildings sectors. The U.S. set a record for the most "cooling-degree days" (as defined by the Energy Information Administration) since at least 1990 causing Americans to use more air-conditioning to remain comfortable. The number of "heating degree days" bucked a long-term declining trend to hit their highest level since 2014.

Meanwhile, the increase in overall energy use belied slower growth in transportation consumption (up 0.7 percent), as Americans continued to buy larger, less fuel-efficient cars, but vehicle miles traveled leveled off.

Electricity demand as measured in terawatt hours grew at a slower pace of 2.2 percent. In other words, although overall energy productivity (a comparison of energy consumption and GDP) declined in 2018, the U.S. continued to grow more productive and efficient in its use of electricity.

Federal Policy Recommendations for the 116th Congress

BCSE supports a range of policies that share bipartisan support and we hope will be enacted in the 116th Congress in the areas of infrastructure, research, development and deployment and tax policy.

Maintaining strong levels of funding for research, development and deployment initiatives at the Department of Energy is critical. Thanks to the leadership of this Committee, the 115th Congress enacted strong funding bills for DOE's Office of Energy Efficiency and Renewable Energy, Office of Electricity, Office of Fossil Energy and other key areas at the agency to ensure the U.S. invests in energy innovation. BCSE believes that Congress and the Trump Administration should once again support this critical area for the U.S. economy, U.S. competitiveness and job creation.

BCSE also views infrastructure as an area of bipartisan support and interest and has compiled a range of policy ideas from its members related to infrastructure modernization and resilience. These span the topics of streamlining permitting and siting, electric transmission, energy efficiency in buildings and resilience and infrastructure financing.

One focus of the Committee has been in the area of hydropower. BCSE greatly appreciates and thanks this Committee for the hydropower provisions adopted last year as part of the America's Water Infrastructure Act (AWIA). Those provisions were an important first step, but additional comprehensive licensing reforms are still needed. We hope that provisions like those contained in last year's bipartisan Senate energy bill will be advanced in this Congress. BCSE looks forward to discussing these ideas, as well as others, with Committee members in the weeks ahead.

Tax policy has been a leading federal energy policy for over a decade. As such, it is essential to enact the energy tax extenders for energy efficiency and the non-wind Production Tax Credit technologies (hydropower, waste to energy, biomass, biogas and geothermal). This is needed to provide a more even competitive environment for investment in these sectors. With the bipartisan introduction of the Tax Extender and Disaster Relief Act of 2019 on February 28 by Senate Finance Committee Chairman Chuck Grassley and Ranking Member Ron Wyden, BCSE hopes this can move quickly this session. BCSE also supports a range of other energy tax related measures addressing sectors such as building efficiency, energy storage and sustainable transportation.

To address global climate change, alignment is needed between the private sector and policies at local, state, regional and national levels. On a national basis, BCSE supports federal legislative action to address climate change mitigation and to improve resilience. The congressional hearings over the past month show a renewed and bipartisan focus on federal climate change policy. Critical to any climate change policy is that it be market-based and inclusive of the broad range of readily-available clean energy technologies that can reduce emissions – affordably and reliably. Smart policies will focus on leveraging private sector investment and send strong and long-term market signals to reduce emissions.[6]

[6] *See*, BCSE Climate Change Statement, available here: https://www.bcse.org/images/2019%20Clean%20Air/BCSE%20Climate%20Change%20Policy%20Principles%20(2019).pdf.

Conclusion

To maintain a diverse portfolio of energy technologies, Congress should formulate and enact stable, long-term policy frameworks that will support the deployment of the full scope of clean energy technologies in a meaningful way. These measures span power generation, building efficiency and transportation and can provide significant public benefits in the areas of energy reliability and security as well as environmental, economic and jobs benefits.

BCSE looks forward to working with this Committee to achieve these objectives. For questions or further information, please contact Ruth McCormick on the Council's staff at rmccormick@bcse.org.

The CHAIRMAN. Thank you, Ms. Jacobson.

I appreciate all that you all have contributed this morning in reminding us what the role of this Committee is in this broader debate. And the fact that you all speak to the R&D piece of it, how important it is to be building out these technologies that will allow us to reduce our emissions, just be more responsible environmental stewards as a general practice.

I like to say that we should have a "no regrets" policy. Regardless of the direction that things go, you know, we are doing the right thing for the right reasons. So you have reminded us of that.

My colleague, Senator Cassidy, has to relieve another colleague on the Floor of the Senate here in just a few minutes, so I am going to yield my time to him.

Senator Cassidy.

Senator CASSIDY. Thank you.

I have been floating in and out, but I have really enjoyed your testimony. By the way, my staff gave me some other interesting stuff.

Mr. Medlock, first let me just say that four-year-old who will find the next innovation is currently playing with Legos is clearly my grandson. Okay? I will just tell you that.

[Laughter.]

So, Sam, if you are listening out there on TV to Papa, we are relying on you, buddy.

The other thing I will point out. You mentioned and I am struck how New York will not allow pipelines to be built through New York to bring natural gas to New England, and you point out though that New York has benefited by transitioning off of coal, among other ways, by using natural gas. My staff pulled together for me the average monthly industrial bill, the cost per kilowatt. In New York it is 5.92 cents. In New England it is 12.54 cents. And so, the inability to get cheap natural gas to New England has given New York a competitive advantage in attracting industry. This is economic warfare by other means. Now I see why Governor Cuomo is so stringent upon that.

And I will share this with you, Senator King, because it is remarkable. The average price of kilowatts, industrial in New England is 12.54 cents and in New York it is 5.92 cents. Why would an energy intensive enterprise move to New England? In Maine, in particular, it is 9.20 cents, and you were the cheapest. Consider poor Rhode Island at 14.57 cents. So anyway, that said, Governor Cuomo has a good thing going.

Ms. Jacobson, you mentioned this and so—no, I am sorry, let me stay with you, I think it is Mr. Medlock—let me go back to the testimony.

Taking the different pathways of California and Texas and I think I see here the industrial cost in California is 20 cents per kilowatt-hour. No, 12.73 cents per kilowatt-hour, and in Texas it is 5.45 or something such as that. Clearly that would have an impact upon the industrial base.

Ms. Jacobson, I think you were speaking to that. To what degree do the costs per kilowatt-hour influence whether industry will establish itself in one state versus another or, indeed, one country versus another?

Ms. JACOBSON. Well, thank you very much for the question and I would just note, looking at the nation across the board to start, the Fact Book has really good data on how we compare with our retail electricity prices versus other competing nations.

Senator CASSIDY. But hang on, but stay with the industrial.

Ms. JACOBSON. Yeah, sure.

We're number two to Canada amongst our major global competitors, because we have low electricity prices as a country.

In terms of state-to-state decisions, I mean, of course, there's a lot that goes into what would determine whether one, you know, facility would go into one location versus another. But certainly having low, predictable electricity costs is key.

And I think——

Senator CASSIDY. So let me stop you for a second.

If you exclude hydro, it does seem as if the cost basis for states more relied upon renewable tends to be higher than the cost basis for those who are reliant upon natural gas.

I have been struck, say, the Green New Deal which is obviously a hot topic of conversation. I have read a report by academics that it would cost, if we were to decarbonize between now and 2060, it would cost, what was it? Thirty trillion dollars or something? Trillions of dollars and that is over 50 years as opposed, or 40 years, as opposed to over 10 years.

If we were to say that decarbonizing would dramatically increase the cost of transmission and of production and therefore, of use, what would that do to the United States industrial base?

Ms. JACOBSON. Well, when I look at the data, I see a very different story. We have a diverse electricity sector now and costs for business and consumers are near record lows.

Senator CASSIDY. Well, I accept that.

Ms. JACOBSON. So——

Senator CASSIDY. But that is with, I think I mentioned both you and Dr. Medlock spoke about natural gas, kind of, allowing that transition to a lower carbon footprint but at the same time keeping those prices a little bit lower. Did I misunderstand you?

Ms. JACOBSON. No, I agree the portfolio is essential. And I think if Congress is going to make forward looking policies, it should do it recognizing we need all the resources available to us and not to pick a technology over another. We really need to have the ability to evolve and, you know, we can't anticipate the future.

Senator CASSIDY. Got it.

Dr. Medlock, any comments on that? To what degree do, I mean, we just have to provide jobs for working Americans and obviously lower cost electricity is part of that. To what degree could we completely transition away from fossil fuel and still have a low enough rate structure as to facilitate the creation of those jobs?

Dr. MEDLOCK. Well, this is exactly why I highlighted the role of innovation, the role of R&D, because if we're going to talk seriously about long-term economic health of this country, it's got to be a combination of, to use a trite phrase, "all-of-the-above." But the only way to do that and address a lower carbon footprint is through basic R&D in things like carbon capture, energy efficiency. All of these things matter.

In fact, when you start talking about energy transitions in addressing local community needs, it's not just about clean energy. It's also about urban planning. It's also about how you actually think about things like infrastructure resilience.

Senator CASSIDY. And so, to play off of what Senator Manchin was saying in his opening statement, knowing that Asia will continue to use coal, part of that innovation will be, as you say, what do we do about the carbon footprint of a resource that is going to be used, period, end of story.

Dr. MEDLOCK. That's precisely the point, yes.

Senator CASSIDY. Yes.

I am out of time, and I yield back. Thank you for——

The CHAIRMAN. Thank you, Senator Cassidy.

Senator Manchin.

Senator MANCHIN. Thank you very much, Madam Chairman.

And also, I have one of my dear friends and colleagues who has to run to another meeting because she chairs also. I want to relinquish my time right now to Senator Stabenow.

Senator STABENOW. Thank you very much, Senator Manchin.

I first want to thank both our Chair and Ranking Member for an excellent hearing on an incredibly important topic that we are all facing and having to work together on in order to be able to get action on carbon pollution. I am very impressed with the hearing and appreciate the leadership of both of you.

I also do want to debate, unfortunately Senator Cassidy just left, but it is actually my six-year-old grandson who is going to provide——

[Laughter.]

He is unbelievable. He is putting together robots with Legos and making them talk. I am not sure how he is doing that, but I am looking forward to his leadership as well as all of our young people.

First, let me just say welcome to all of you.

And Mr. Schutt, when you talk in your testimony, written testimony, about describing new words that are now needed to explain what is happening on climate change, boy is that real in Michigan right now.

We have been the epicenter, whether it is the polar vortex and what is happening because things are heating up, the cold air is floating down. We are getting hit with it. I know those are not scientific terms, but that's how I view it.

Secondly, last weekend we had something, a new term called a "bomb cyclone" which was 60-mile-an-hour-plus winds, and I had never heard of that term before. It is extraordinary what is happening.

And so, we have a lot of work to do, and there is a real sense of urgency about it. And even though there are those, including the Administration, that continue to deny climate change—we all know—and the business community is moving forward, others are moving forward as we need to, aggressively on this.

So I am really glad NextEra, and I am glad that in Michigan our two utilities, DTE and Consumers, are aggressively moving forward on wind and solar. I think they are real leaders. They have a plan to reduce carbon emissions by 80 percent and at least 50 percent clean energy by 2030. And we are a state that until re-

cently was 70 percent coal production. So, in terms of—I don't mean production—reliance on coal, so Michigan is now the leader in the Midwest.

I would just say to my Ranking Member that we are creating jobs, those clean energy jobs that we have all been talking about. And I want them all in Michigan, but we would be happy to let a few go to West Virginia but there are 8,000 parts in a big wind turbine and we can make every one of them in Michigan. And when I last was in Alaska, I saw some, actually wind turbines made in Michigan which I was very proud to see.

So, Dr. Tierney, and I think also Dr. Medlock, you mentioned this as well, but when we look at what is driving the reduction in coal generation at this point, rather than it being federal regulations, would you comment again on the fact that low natural gas prices, sharp drop in costs of renewable energy, is that, in fact, what is driving it? And secondly, if the answer is the latter, what are the environmental benefits of deploying electric vehicles, near and dear to my heart in Michigan in terms of our leadership, with a generation mix that is rapidly becoming cleaner which I know is essential to that in terms of carbon pollution reduction?

Dr. TIERNEY. Thanks for that question.

And with all due respect, Mr. Owen Cory Tierney is going to be the one playing with Legos.

Senator STABENOW. Oh, well.

Dr. TIERNEY. He's only one.

Senator STABENOW. Competition.

[Laughter.]

Dr. TIERNEY. But they're all going to be there. It's great.

Senator STABENOW. They are. They really are.

Dr. TIERNEY. Your question tees up a central issue for the jurisdiction of this Committee. It's about technology and innovation and markets.

When I think about the Committee's jurisdiction over both FERC and encouraging competitive markets on the electric side and on the gas side, and when I think about the innovations that have come through funding, through authorizing activities at the Department of Energy, it goes to your question perfectly.

First, we've had flat electricity demand in huge part as a result of the energy efficiency technologies as well as standards that have been set by the Department of Energy. Second, when you think about the cost reductions that have taken place on the renewable energy side, again, that has been driven in large part by investments to increase the productivity and performance of renewables.

And in fact, when Senator Cassidy asked about the competition between electricity, excuse me, natural gas and renewables, I'm thinking of Senator Gardner because in Colorado, Xcel Energy procured renewables at lower cost than a supply from a natural gas facility.

But all of those activities, including the production of natural gas, have been accomplished through investments in applications of advanced technologies. So, that's cool. Those are all contributing to the story on the electric side and now on electric vehicles. They are very cool.

If one wants to reduce greenhouse gases and one wants to do it affordably, then cleaning up the electric sector is key and then using electricity to fuel other things like vehicles.

So if that's the only goal, that's a terrific one for Americans. But the goal of economic development is also really key, of course, you want those jobs. And for the U.S. to remain positioned in an international market where foreign companies from Europe, from Asia, on the Asia side not only Japan and Korea, but also China, they are going with electric vehicles. So for the U.S. to remain competitive in an international as well as domestic market, this is a great opportunity.

Senator STABENOW. Thank you very much.

Thank you for allowing me to jump ahead. Thanks.

The CHAIRMAN. Thank you, Senator Stabenow.

Let me just very quickly turn to you, Mr. Schutt.

I often use the State of Alaska as a case in point for why the innovation and technology, R&D, particularly microgrids, can make a difference in real time in a place like Alaska.

Senator Cassidy mentioned some of the prices that some are paying in the Northeast and in New York. As we know, we have some communities in our state that pay in excess of $1.00 a kilowatt-hour. These are obviously not sustainable and so that drives a level of innovation that, I think, most people don't recognize and don't appreciate.

In your written testimony you describe the Rural Energy Initiative. You have indicated how we are utilizing some systems to deal with permafrost to keep the permafrost cold through these passive systems.

You have innovation that is happening within the sewer and water systems, recognizing that in far too many of our communities, we still lack basic sanitation. We don't have running water. We don't have a place where you can flush a toilet, and you have a washateria that the community uses to bathe and wash their clothes in. So we deal with some pretty tough conditions.

Can you just quickly speak to what we are seeing from the Rural Energy Initiative and how, again, through the innovation and the pioneering that we are seeing in some far away spaces, oftentimes working with our national labs, how we are working to not only reduce the cost of energy but improve the lives of people because when you have safe drinking water, when you have the ability to just stay warm in your house that isn't filled with mold and contributing to respiratory issues, what it means for a family?

Mr. SCHUTT. Sure. Thank you for your question.

I think Alaska is something of a national lab for these innovative technologies around energy.

The pipe penetration of renewables into microgrids which doesn't seem like it's a close relation but as the deployment of renewables on, particularly, solar PV on rooftops of businesses or homes gets more and more pervasive within the system, the physics behind the substation at a distribution level look a lot like an isolated microgrid in a rural community in Alaska.

And so, we have, as a state and as energy leaders in the state and researchers have done a lot of research around the integration and high penetration of a variety of renewables, not just wind, not

just solar, but heat pumps, hydrokinetics, micro wind, which is, I think, a little bit different, geothermal and also storage. And I think within that space we have two communities that stand out at a larger scale for doing things that are, sort of, unheard of and not thought of at some level.

One is—Kodiak is effectively a 100 percent renewable electric utility, Kodiak Electric Association. Now that, I recognize, requires a unique set of circumstances and driven in part by the economics of being otherwise a diesel-reliant community. And so, they have a large hydro resource, but they also have nine megawatts of wind and they have also had to bring on two different forms of electric storage in order to make this whole system work.

The other is Cordova which is a little bit smaller, but they have 100 percent buried distribution of the transmission grid which is, sort of, unheard of also. And I think that as you have these more dramatic climate change weather events, the resilience of a completely buried distribution system is quite different and quite a bit more resilient and reliable for the community.

So we are doing a lot of interesting things, and we do have a lab in Fairbanks at the Alaska Center for Energy and Power at the University of Alaska Fairbanks that does a lot of research, primary research with these, kind of, balance of plant and other technologies that are around the energy technology itself.

I think we have an applied lab in Alaska in both a formal lab sense as well as in rural communities where, kind of, the desperation of the local economic reality drives innovation and innovation drives the reality of practical applied engineering.

The CHAIRMAN. That was well said.

We invite everybody to come up.

Senator Manchin.

Senator MANCHIN. Thank you, Madam Chairman.

I am so glad that we are having this hearing, and Senator Murkowski and I have talked about it. And a lot of people, you all probably have evolved over the years of how you believe or where you get your information. You might have changed your position on climate. Is climate change real? Is it biblical proportion time or—the last, I think the last century there is no doubt that humans have made a tremendous impact on what we are dealing with.

Very quickly, can you tell me where you get, basically, where you get your facts that support your position? If I just know where you are coming from, because we are trying to get to where we are all on the same sort of facts and where we are getting our information. And you all, being the experts you are, might have a better insight. So if you could quickly go down the line and just tell me where your facts come from.

Mr. Kelliher?

Mr. KELLIHER. Mine come from the U.S. Energy Information Administration, part of DOE. Some of the cost decline projections come from Lazard analysis that looks at the levelized cost of energy. The one I cited was from November of last year. And then there's also the analysis on battery storage that came from BNEF.

Senator MANCHIN. Mr. Schutt?

Mr. SCHUTT. I get my facts from a variety of the government sources, U.S. EIA, private industry, BP's Annual Energy Outlook

and then, what my wife would call, an inordinate amount of time on the Internet trying to figure out what's real and what's not and——

Senator MANCHIN. I mean, here is the only thing, as you all go down here. People basically that differ with you or disagree with you are getting their facts or saying they are getting facts from different sources. Have you looked into those sources saying, that's not real news? That is just not real facts. That might be the distorted facts.

So, yes sir, Joe.

Mr. KELLIHER. Can I respond to that?

Senator MANCHIN. Yes.

Mr. KELLIHER. One fact that is frequently misstated, I have to think knowingly or maybe it's a matter of faith——

Senator MANCHIN. Okay.

Mr. KELLIHER. ——that our electricity supply is losing diversity. The exact opposite is true, and you can prove that mathematically——

Senator MANCHIN. Okay.

Mr. KELLIHER. ——by taking, summing the squares of the different components of our electricity supply in different points, different years.

Senator MANCHIN. Yes.

Mr. KELLIHER. And I did that recently and it's, we are 50 percent more diverse.

Senator MANCHIN. You were able to diffuse that, right?

Mr. KELLIHER. We're 50 percent more diverse——

Senator MANCHIN. Diverse than we were.

Mr. KELLIHER. ——mathematically, objectively using GI data, than we were in 2005. So, that——

Senator MANCHIN. You debunked that one, okay.

Dr. Tierney? Where do you get your facts?

Dr. TIERNEY. I spend all my time looking at facts. So, on the energy side——

Senator MANCHIN. Which ones do you believe?

[Laughter.]

Dr. TIERNEY. I follow data collected by the U.S. Government through the Energy Information Administration.

Senator MANCHIN. EIA.

Dr. TIERNEY. It provides a tremendous range of facts that are provided by industry——

Senator MANCHIN. And you have cross-checked that to make sure that it was accurate? You feel the accuracy of what you are getting is by cross-checking?

Dr. TIERNEY. I am quite familiar with it. I was the Assistant Secretary for Policy at the Department of Energy. I'm very familiar with the EIA and its work. They do great work.

Senator MANCHIN. Okay.

Dr. TIERNEY. I have followed the IEA, the International Energy Agency.

Senator MANCHIN. Yes, there is a little discrepancy between the two in some of the information we have received.

Dr. TIERNEY. In forecasts, yes.

Senator MANCHIN. Okay.

Dr. TIERNEY. I think there's a lot of historical information that is quite——

Senator MANCHIN. The IEA was more accurate than our EIA when they forecasted in 2012 or 2015 that the United States would be the leading producer of natural gas. No one thought that would ever happen.

Dr. TIERNEY. That's true.

Senator MANCHIN. How did they hit it right and we missed it?

Dr. TIERNEY. The EIA, when it forecasts which is different than facts for historical records.

Senator MANCHIN. Okay.

Dr. TIERNEY. Which is what I was talking about originally, when they forecast, they forecast based on known policy as it exists today——

Senator MANCHIN. Yes.

Dr. TIERNEY. ——in the United States.

Senator MANCHIN. Gotcha.

Dr. TIERNEY. And so, there's some differences.

But may I just also say——?

Senator MANCHIN. Very quickly.

Dr. TIERNEY. I get my facts on what's happening with the climate change from the International Panel on Climate Change, IPCC.

Senator MANCHIN. Okay.

Dr. TIERNEY. As well as the National Climate Assessment. I was a co-author of the Energy Chapter of that. They do great work.

Senator MANCHIN. Dr. Medlock?

Dr. MEDLOCK. A variety of sources. I use government sources. I use IEA. I use research networks. I actually participate in conferences with people who are involved in climate research. So——

Senator MANCHIN. Have your opinions changed since more facts have come out? Have you changed your opinion on climate change?

Dr. MEDLOCK. I don't think I've ever had an opinion on it.

Senator MANCHIN. Okay. Or your support of it, or your belief.

Dr. MEDLOCK. It's really, it's a data-informed exercise. And you know, scientifically, we've known, you know, that CO_2 is a forcing agent for a century. This is not new information. It's always been about, you know, what's the degree to which it's actually impacting things? And that's where research is opening doors, opening things.

Senator MANCHIN. Great.

Ms. Jacobson?

Ms. JACOBSON. Thank you.

Business Council and its members get a lot of the same information from the same datasets and we decided about seven years ago to put it together in a free basis for the public and for policymakers.

It also, I think it's important to check in with industry, the historical data is very strong. We're really blessed by the investments that our government has made.

And you know, just a plug for one other opportunity, you know, this jobs data that we're seeing is very significant and the U.S. Government has supported that type of endeavor before to track U.S. jobs across the board. I hope that the U.S. Government will continue to look for areas to capture that data. It's now being done by outside sources. But again, this Fact Book and we brought cop-

ies for everybody, the Committee and their staff, is again available for free online and it uses government sources, industry, other independent analysts.

[The Fact Book referred to is available at: https://bcse.org/wp-content/uploads/2019-Sustainable-Energy-in-America-Factbook.pdf]

Senator MANCHIN. It is a website.

Ms. JACOBSON. Off of the Business Council's website. It's done independently by Bloomberg New Energy Finance. We commission it each year, but it's BCSE.org.

Thank you.

Senator MANCHIN. BCSE.org.

Ms. JACOBSON. But again, we have copies for anybody who would like one.

Senator MANCHIN. Thank you all so much. We have more questions coming.

The CHAIRMAN. Thank you, Senator Manchin.

Senator Gardner.

Senator GARDNER. Thank you, Madam Chair.

Ms. Jacobson, if you could just talk a little bit more, in your testimony you talked about energy savings performance contracts. This Committee, myself along with a number of my colleagues, have tried to pursue additional energy savings performance contracts (ESPC). Could you talk about a few steps the government could take to encourage even more ESPC success?

Ms. JACOBSON. Well again, this is an area where I want to commend the Committee for its attention. I mean, as you know well, I mean, one of the benefits of energy savings performance contracts is because of the efficiency opportunities we have in the economy.

The private sector can partner with building owners and others that are looking to enhance their energy infrastructure and buildings and without any outlays by those property or facility owners, they can partner with companies that will go in, just based on the energy savings alone, and provide those retrofits and a guaranteed performance of those facilities.

So that what the Federal Government can do is, you know, they've already permanently authorized that ability for federal facilities to utilize that mechanism. And there's also a utility counterpart mechanism.

But leadership, I mean, that was a huge driver in the last five to seven years for uptake in ESPCs. If the Federal Government would once again take on an ESPC challenge, I think it would regalvanize the energy around using that mechanism in federal facilities again.

Senator GARDNER. Should we take an approach that may be like requiring different agencies to meet certain targets either through a dollar amount, a percentage amount of ESPCs?

Ms. JACOBSON. Well, I wouldn't want to dictate what the appropriate discreet mechanism is, but we need a pathway to invest on and something that will drive the market to looking at ESPCs. So I would say anything that you can do to provide that direction.

And then, the reporting and accountability is critical. We can set a goal, but if there isn't a mechanism to check and make sure that we're achieving those goals and learning from where we are doing

well and where we're falling short, then we won't really capture the benefit of that type of mechanism.

Senator GARDNER. Because we are talking billions of dollars in energy savings, correct, and thousands of private sector jobs that can be created if we do this in an expanse that we could?

Ms. JACOBSON. Yes.

And again, and not on the taxpayer burden.

Senator GARDNER. Right.

Ms. JACOBSON. I mean, this is things that taxpayers don't have to put the outlays for but I would just say also, it's just thinking about the roles of government either serving our veterans or helping with basic services. You know, we are just improving the quality and performance that the Federal Government investments are providing to U.S. citizens by using mechanisms like this.

And I would also say it can enhance our resilience as a country.

So making these kinds of investments in buildings and in government facilities as well as in our schools and hospitals and other critical infrastructure is extremely important.

Senator GARDNER. Thank you, Ms. Jacobson.

Mr. Kelliher, you talked about the shale revolution, how it, in your testimony, the dominant driver of recent changes in electricity markets and the reduction as well that we have seen in solar and wind costs both being contributing factors to, sort of, this electricity matrix that you are talking about.

Do you suppose that the last 30 years, can you comment on how the last 30 years' worth of DOE R&D investment, research and development investments in both new extraction technologies as well as investments in solar and wind, might have helped set the stage for those technologies? I mean, when I grew up "damn wind" was one word. And now it is nice to see that we are actually utilizing what was such a common resource in Eastern Colorado.

Mr. KELLIHER. Sure. Thank you.

I would actually love to know the answer to that question. I've always wanted to know what was the contribution from DOE's R&D program and what was from the private sector's R&D. I don't know the answer to that. But I think—I don't think it all came out of DOE, the DOE labs, but I think they played an important role.

Senator GARDNER. No doubt they played an important role.

Mr. KELLIHER. Yeah, I think they did. I just, I've always wanted to know what was the relative contribution.

Senator GARDNER. Right.

Mr. KELLIHER. I don't know the answer to that.

Senator GARDNER. Would sort of the same focus that we took on research and development through DOE and perhaps other agencies, if we made that sort of investment in carbon capture or advanced nuclear technologies to help make and add more carbon free choices, would that be a boost to our efforts?

Mr. KELLIHER. I think it would be. I think that the same sort of line of thought that the future technological developments won't all come out of the DOE labs but some of it will and a lot will come from the private sector.

I will try to find the answer to your question though. I'll try to follow up and find out is there analysis that shows what was the

contribution of the labs to the improvements in wind and solar technology.

Senator GARDNER. Senator Heinrich and I have been working ITC investment tax credit language for adoption of new technology in storage. Would something like that help as well as we develop new renewable clean energy technologies?

Mr. KELLIHER. Yes, and that's, sort of, there's a little hurdle for storage to qualify for some of the current tax incentives. And that's something that could be addressed because I think Congress—storage really is a fundamental change. Electricity is the one commodity that cannot be easily stored. But battery storage can change all that.

Senator GARDNER. Very good. Thank you, Mr. Kelliher.

Mr. KELLIHER. And tax incentive might help.

Senator GARDNER. Thank you.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator Gardner.

Senator Wyden.

Senator WYDEN. Thank you, Madam Chair. And Madam Chair, to you and Senator Manchin, thank you for putting together this very important hearing.

Mr. Kelliher, first of all, thank you for your kind words about what Oregon is up to in terms of wind, solar and storage. We took special note of that.

I am going to ask a question of you, if I could, Ms. Jacobson, because you have essentially been making the argument and making it for some time that a smart tax policy would really generate growth in innovation in clean energy in the years ahead.

As the Ranking Democrat on the Senate Finance Committee, I have essentially proposed taking the 40 energy tax provisions that are on the books now which, in my view, basically subsidize the dirty energy relics of yesteryear. I propose throwing them in the trash can and substituting one for clean energy, one for clean transportation fuel and one for energy efficiency because I think this would make a real difference in promoting innovation, cleaner energy, helping us to shake the carbon habit.

So the question I wanted to ask of you, because I don't want to get you in the how do you feel about this bill or that bill and endorsing pieces of legislation because I know that with your organization that is problematic. So let's just talk conceptually. From a conceptional, concept standpoint, don't you think that there would be even more innovation and more opportunities to grow clean energy if Congress basically junked the energy provisions in the tax code and replaced them with what I think you and I would call a "technology neutral approach?" What is your take on that?

Ms. JACOBSON. Well, thank you very much for the question and as you know well and you know, federal tax policy has been a major energy policy of the last several decades. And when you look at what's happened through the production tax credit or the investment tax credit when they're active, when they're not active, when they've been extended for a short period of time versus a long period of time, the market responds very quickly and affirmatively.

So, I think, I'm looking, you know, at the legislation that you introduced last year but has been contemplated for a good number

of years, the Clean Energy for America Act as an example. As you've described, you've tried to articulate a policy that's not looking at one technology versus another but how can we set a goal for the electricity sector and for energy efficiency and enable a long-term investment pathway incentivized by the tax code to support the types of investments that Congress is seeking.

And by putting it on a longer timeframe and setting a common metric, we're moving away from the uneven policies that we've had before that hit different industries and different businesses in very different ways.

And even though things like the production tax credit or the investment tax credit have sought to deploy a grouping of technologies, because of those businesses and investment cycles, not all have benefited. I mean, hydropower is a good example, but we could look at biomass. We could look at waste to energy. Now this conversation on storage.

New technologies are coming into the marketplace. And these policies, you know, need to adapt to the marketplace of today. So I really commend your leadership on thinking about a revised, refreshed and current framework for energy tax policy.

And I very much look forward to having our members further comment on your proposal and seeing it move through the Committee process.

Senator WYDEN. Well, thank you and we are going to want to work closely with you and, obviously, the Chair and the Ranking Member.

To me, and I see one of our colleagues, our Senator from Nevada, who just joined the Committee, I think that if you are running a company and you make a change on your factory floor, you are always going to buy something that is more innovative, more energy efficient and cleaner because you are not going to be able to explain to your investors if you are doing otherwise. And so, it seems to me this would be a benefit across the board and my sense is, and I am exploring this, if you are running a public company, I am not sure you even meet your fiduciary obligations in a public company if you were to buy something less energy efficient and dirtier than what was already on the factory floor.

So thank you for your straightforward and supportive take of a technology neutral tax policy in the energy space. We are going to be calling on you often and, of course, working closely with the Chair and the Ranking Member and my new colleague on the Finance Committee from Nevada who has had a great interest in clean energy as well.

I appreciate the Chair, again, and Senator Manchin, for holding this important hearing.

The CHAIRMAN. Thank you, Senator Wyden.

Senator Cortez Masto.

Senator CORTEZ MASTO. Thank you, and thank you, Madam Chair and Ranking Member. This has been incredible, this discussion so far.

Actually I was going to lead with that question. Let me just clarify because when you, Ms. Jacobson, in your written testimony, say to address climate, global climate change, alignment is needed between the private sector and policies at local, state, regional and

national levels, is that what you were referring to in your conversation with Senator Wyden, that type of alignment or is there more that we can do to align, to address climate change?

Ms. JACOBSON. I think at the broadest level, it's to be mindful of what's going on at all these different levels of investment decision-making. So in part, it's what's going on with private companies when we're seeing increasingly, they're taking advantage of low renewable power prices and procuring record levels of renewable power.

We are seeing states and cities and regional bodies take action across the board as it relates to energy and electricity, and some of those are environmental policies and some of them may be a range of other policy objectives.

But from a tax perspective at the federal level, you're sending a very strong signal of what you're trying to encourage through tax policy. And as we've seen over the last several decades, energy tax policy has been very powerful and effective.

Senator CORTEZ MASTO. Right, right.

Ms. JACOBSON. So if we're looking at that as one of the options to drive either greenhouse gas emissions or other energy sector investments, I think the benefit of having a forward-looking policy that hopefully is long-term enough so that all technologies can participate and that allows all technologies to participate is key.

So it has to be in line with the investment cycle. So that's the alignment with the private sector. It needs to be mindful of the trends in the country which we've been talking about which are, you know, looking to decarbonize the electricity sector.

And it has to be factoring in, you know, how the Federal Government's role can be and the tax code, you know, is probably, I wouldn't say the most important, but certainly one of the most important drivers the Federal Government has to direct investment.

Senator CORTEZ MASTO. Okay.

Are there any other drivers or anything else we should be looking at other than utilizing the tax code?

Ms. JACOBSON. Definitely.

Senator CORTEZ MASTO. What else?

Ms. JACOBSON. I mean, I think research, development and deployment which we've talked about.

Senator CORTEZ MASTO. We have talked about, yes.

Ms. JACOBSON. I think, you know, other opportunities to streamline investment in the electricity sector is key. You know, we talked about the oversight this Committee has with FERC. There's a tremendous amount of activity going on there. Things like building codes and standards for the energy efficiency industry are really critical to enable cost benefits for consumers, as well as environmental savings.

So there's complementary energy policies that might go along with things in the tax code or maybe very specific policies. We haven't really talked about it much here, but you know, market-based mechanisms to address carbon emissions.

Senator CORTEZ MASTO. Right.

Ms. JACOBSON. So, you know, there are tax policies being contemplated. There are, you know, cap and trade type policies being contemplated.

So there might be some very discreet policies that might be looked at, you know, not alone in this Committee, obviously. This Committee's jurisdiction is not on emissions but EPW and other committees may be looking at discreet policies that will, again, send that market signal throughout the economy to lower our greenhouse gas emissions.

Senator CORTEZ MASTO. Thank you.

Mr. Schutt, thank you for being here.

Let me just say, I was looking at your website. I so appreciate you being invited today, because I think there is this nexus between what is happening in our climate and health care, health care to individuals, health care to individuals and we don't talk enough about it. So I appreciate you being here.

I noticed under your website you have a Center for Climate and Health. Can you talk a little bit about what that center does? Does it address the health care needs of members in your community or, if you don't mind, kind of, just expanding on it a little bit?

Mr. SCHUTT. Sure.

So that center is addressing a number of the health care impacts in rural Alaska. A lot of it does relate to the water and sewer issues and in support of the development of new water and sewer projects or the rehabilitation of existing projects, the energy efficiency that I mentioned earlier in the operations of the existing projects. But there are also other initiatives around indoor air quality and other factors, environmental health factors that impact human health.

So one of the ironies around energy conservation and efficiency is that the more you insulate a house, particularly in a retrofit type of a situation, the more you contend to create indoor air problems. So there are other initiatives around air circulation and getting fresh air into the homes. So that particular group is fairly small and they deal with a whole host of practical and applied issues, but you are correct around the basic thrust of what they do.

Senator CORTEZ MASTO. Thank you.

I notice my time is up. Thank you.

The CHAIRMAN. Thank you, Senator.

Senator King.

Senator KING. Thank you, Madam Chair.

First, I want to thank you and the Ranking Member for this hearing. It has been absolutely fascinating and important, very important and thank you for inviting me to Alaska so I could see some of these issues.

I still tell people about arriving at a remote village by driving on a frozen river. That I had never experienced before. And a lot of these issues are right on the front lines of the people of Alaska.

Ms. Tierney, I loved your testimony and some of the graphs that you present are just really fascinating. One that really struck me was Figure 5 where it basically has a line that says this is where we would have been if nothing had happened in terms of utilization of electricity and sources. And what it shows is that 50 percent of the reduction in carbon output was because of efficiency which we don't think of. We talk about solar and wind and natural gas and all these other things, but just using electricity, the cheapest, cleanest kilowatt-hour is the one that is never used.

I think we need to remind ourselves of that and your chart was one of the most powerful. Half of the reduction was from more efficient use of power, one-fourth is from switching to natural gas and one-fourth is to the growth of renewables. So I think that is an important point. I want to thank you for that.

With regard to natural gas, the concern I have, and I have always been an advocate of natural gas, particularly as a transition fuel because it is so much cleaner. But it is growing so significantly. In New England now, it is 50 to 60 percent of our electricity source. I worry about overdependence.

I think diversity is very important and we are talking about a commodity that is at a very low price, but it is a price that can change. And that dependence, it seems to me, could create a serious problem if the price changed because of world commodity markets. Do you share that concern?

Dr. TIERNEY. Yes. It may not be obvious but I spent 35 years in New England. I lived in Boston for many years and am very familiar with the circumstances associated with increasing reliance on natural gas.

Senator KING. Like me, as a New Englander then, you are probably happy that when the Patriots won the World Championship it ended a terrible three-month drought between world championships for Boston and New England.

Dr. TIERNEY. Woo-hoo.

[Laughter.]

Senator KING. No, go ahead, sorry.

Dr. TIERNEY. So yes, they're, I think, becoming too dependent on any fuel is not a great idea. And the story that you're describing of New England's rising concerns about the extent to which competition for a limited amount of natural gas, especially during winter, is a problem. You're either going to have to put it in homes, industries and/or power plants.

So New England has been trying to diversify by looking at alternatives, as you know. And I think that's one of the messages I hear from everybody on the panel which is don't choose some horses and then ride only those horses.

Senator KING. Diversity of supply is a key.

Dr. TIERNEY. Absolutely.

Senator KING. Mr. Medlock, I want to ask you a question. Does the grid itself need substantial modification to support greater electrification?

Now it seems to me, for example, in transportation most people are going to charge their cars at night. And as you know, there is significant additional capacity available on the existing grid at night and on off-peak hours.

Talk to me about what we are going to need, if anything, in terms of modification to the grid itself. I am not talking about energy sources, I am talking about transmission and distribution, in order to accommodate greater electrification.

Dr. MEDLOCK. There is a significant amount needed with regard to grid infrastructure upgrades, new investment and the like.

I think if you talk to anybody who has, you know, spent their career in the electric power sector, you never plan to the optimum, you plan to the suboptimum.

And so, you made a statement, everybody is going to charge their cars at night. Well, that is what we hope would be the case but that might not be——

Senator KING. Mine is charging right now——

Dr. MEDLOCK. Well, there you go, so but the point is, is you actually have to have a grid that's flexible enough to accommodate, you know, the whims of the consumer which are very difficult to predict.

Senator KING. So there will be infrastructure needs.

I would appreciate it for the record if you could supply some thoughts on that, what might be needed. Not for now, not now because my time is running out.

Dr. MEDLOCK. Sure.

Senator KING. But if you could give us some thoughts.

Mr. Kelliher, it seems to me, I mean, one of the things that has come out of this, storage is the big deal. It will unlock vast amounts of potential renewable power.

You mentioned battery prices have come down. Where do battery prices have to go in order to make, to be totally competitive with say, a wind and solar plus battery storage system, as you describe in Oregon?

Mr. KELLIHER. Yeah, I think they're at a good price now where they make sense now. We're the biggest renewable company, wind company, solar company, in the world.

When we respond to an RFP for wind, we've started to say well, we'll give you wind plus solar, or if we're responding to an RFP for solar, we're saying here's solar plus storage. And they look at it. So we're giving them, offering them, a product different than what they asked for and we also offer them the pure wind or solar product. And they'll look at the capabilities and it will invite a discussion about well, what do we get with this combined product? And there's actually a lot of interest. It really comes down to with storage is what's the discharge period you're looking for?

Senator KING. Right.

Mr. KELLIHER. And how——

Senator KING. In New England we need some batteries that would last two weeks in January. That is different than an afternoon peak.

Mr. KELLIHER. Exactly. Yeah.

And we are actually building a storage project in Maine.

Senator KING. I know. And you are building a major solar project in Maine.

Mr. KELLIHER. Yes, sir. Yes, sir.

So I think——

Senator KING. So battery cost per kilowatt-hour of output is getting to the place where it is competitive?

Mr. KELLIHER. It's competitive for certain uses.

Now, there's not a two-week, you know, battery storage project.

Senator KING. Right.

Mr. KELLIHER. It's, you know, that's what's changing is it used to be, kind of, a two-hour product, then a four-hour product and so people are looking at well, when will it be eight hours? When might it be longer? What will the costs of that be?

But the costs are still declining. I mean, if you look at solar PV cost declines, they've been——

Senator KING. $70 to $.50.

Mr. KELLIHER. But—and storage is experiencing a similar cost decline and it's still going, it's still declining.

Senator KING. And just to tie a bow on it, research money is critical. Tax policy is critical to encourage this development?

Mr. KELLIHER. Yes.

Senator KING. Yes. Thank you.

Dr. TIERNEY. Not just on batteries but other kinds of storage.

Senator KING. Other kinds of storage, sure. Pump storage, thank you.

Thank you, Madam Chairman.

The CHAIRMAN. Thank you, Senator King.

So a good conversation about the need for diversity of supply and technology neutral and how we build out a grid that works.

You asked the question about is our grid sufficient as we work to integrate these new sources of supply. I think everybody has spoken to that, that you have a combination of policy mechanisms here, market forces, consumer demand, and that has pushed us in the direction where we are seeing the level of natural gas rising and the wind and the solar generation and then the decline in the more traditional baseload resources.

Can we just have a conversation about what that may mean to reliability of the grid? We use the term resilience around here a lot of times. As much as we all want to ensure that we are moving toward reduced emissions, we are lowering the cost. We all want to make sure that when we need it, it is there because when it is not, it is cold and it is dark or it is too hot. Do any of you share the concern that with this, because I think the transformation has been pretty rapid in this past decade here. Does the speed with which we are moving to change up this fuel mix, does it pose greater grid reliability challenges that we are not prepared for?

You mentioned the transmission aspect of it, Mr. Medlock, but anybody jump in here.

Mr. KELLIHER. I don't think there's a threat to resilience from the developments that have been occurring, particularly the changes in the electricity supply mix. And part because the newer technologies, they're much more flexible on performance. They don't have long startup times. They don't have long, minimum run periods. So they're just much more flexible in performance. And I think there's a relationship between diversity and resilience.

And it's also important to remember that resilience really isn't driven by the generation fleet so much as by the wire system, the distribution system and the transmission system.

There's a really excellent analysis that showed that the outage hours resulting from fuel supply emergencies were, this is from the Rhodium Group—Senator Manchin has asked, was curious about sources, it's not my number—is 0.0007 percent. I think that's seven ten-thousandths of a percent of our outages were a result of a fuel supply shortage onsite. Everything else is caused by failures of the wire systems.

So I think the wire system, the delivery system, is the real resilience issue and we need continued investment, because today's grid

was designed in the past for yesterday's electricity supply. We need a different grid as the supply mix changes.

Dr. TIERNEY. Could I add?

I have just left a committee meeting over at the National Academy of Sciences where there is a new committee, of which I'm honored to be a member, on grid modernization. This committee's membership exemplifies the terrific work that's being done at lots of different windows into the resilience and reliability issue. There are aspects of it that are associated with what's your mixture of generation because each type of power plant has really different functionalities. So you need a mix, and I'm going to keep coming back to a mix and the diversity issue.

On the transmission system there's tremendous work being done by the national labs, the Department of Energy's Grid Consortium, Grid Modernization Consortium, is doing great work. They are keeping up ahead of the curve.

There are a lot of people looking at cyber issues, and they are a huge portion of the resilience question. And of course, extreme weather events are critical to all of this.

So we think about integrating more flexible, variable resources and that is a new challenge, and we are finding that the grid operators are handling those issues and keeping ahead of the curve. But, and the industry is so mission-oriented to addressing these other ones. So there's a lot of work being done. And the big challenge is trying to have a grid that can handle a perturbation from any of those kinds of things.

The CHAIRMAN. Dr. Medlock?

Dr. MEDLOCK. Yes.

So one thing I want to highlight is handling the introduction of variable sources of supply, non-dispatchable sources of supply, is not just about the grid. It's also not just about having other flexible forms of generation on the grid. It's also about other market responses such as voluntary load reduction programs.

So large industrial consumers that are connected to the grid actually have the ability to ramp down, and they typically get preferential rate treatment when they do something like this when there's a resource adequacy issue on the grid.

So grid operators are doing a really good job of handling the challenges that are presented, but as we go forward it's going to be important that we increase interconnectivity because that, ultimately, allows for areas that are short resources to draw on areas that are long resources. And that's going to be a very, very important point as we go forward.

The CHAIRMAN. Good, thank you.

Senator Manchin.

Senator MANCHIN. The National Climate Assessment says within the next ten years if we don't make drastic changes as a globe, as the world, as seven billion of us living on Planet Earth, if we do not do something within ten years it could be irreversible of the damage that's done to the climate. Are you all in agreement with that statement, the ten years?

And next of all, if that is the case, you have China over 60 percent reliant on fossil, coal, you have India almost 70 percent reliant. They are not changing any time soon. What do we do?

Just jump right in.

Dr. MEDLOCK. I'm happy to jump on that one.

I will preface my remarks with the following statement. At the Baker Institute we have had the opportunity to host over the last six years, on average, 23 different international, administrative level delegations for conversations about energy and environment. And the one thing that is just remarkably true about every one of those conversations is that they're all different.

And that's eye opening because we all view the world from where we sit. And the reality on the ground in China is very different than the reality on the ground in India, is very different than the reality on the ground in London and in New York, then in Washington, DC.

And the challenges that those governments, local and national, are faced with are in many ways very different. What one group considers the next big crisis may not be considered——

Senator MANCHIN. I mean, is a ten-year cycle, is that a fair statement?

Dr. MEDLOCK. Well that's what I'm getting to. The ten-year, the point about ten years, I don't believe that the world is going to end in ten years, no.

But I think it's important that sitting in the United States in a developed part of the world, we actually lead by example which is why I've highlighted the role of R&D because you look at countries like China, for example. There's 254 gigawatts of coal-fired generation capacity under construction right now. That is larger than the entire U.S. coal fleet at the moment.

Senator MANCHIN. Correct.

Dr. MEDLOCK. So when we think about that, we think about CO_2 as being a problem of the global commons, it really means that we need to lead by example.

Senator MANCHIN. But Doctor, if we are leading by example, we have done scrubbers, low NO_X boilers and baghouses.

Dr. MEDLOCK. Absolutely.

Senator MANCHIN. They are not implementing any of those.

Dr. MEDLOCK. I agree with you 100 percent.

Senator MANCHIN. Well then, how do we lead by example?

Dr. MEDLOCK. The scrubber issue though, is not a CO_2 issue. That's a local air pollution issue.

So I agree with you 100 percent, and that's where it actually comes, it comes down to cost.

Senator MANCHIN. So, basically——

Dr. MEDLOCK. You've got to address things. And this is where innovation has actually been vital. You know, what's the parasitic load of these technologies as we attach them to existing power plants? And that's one of the reasons why they're not actually operated in some places in China, because that lets the costs up.

Senator MANCHIN. It is all cost. I know that.

Dr. MEDLOCK. It's about economics.

Senator MANCHIN. Same thing with carbon capture and sequestration, because it is not basically economically feasible to——

Dr. MEDLOCK. It's not economically feasible now, but neither was shale in 1985.

Senator MANCHIN. Correct.

Dr. MEDLOCK. Right?

And that's my point.

Senator MANCHIN. But I am just saying you said we lead by example. For the last 20 years we have removed particulates from the air in America.

Dr. MEDLOCK. Yes, we have.

Senator MANCHIN. We have closed the old coal-fired plants. They still have not followed our example because either we have to use our trading policies and our, basically, the tariffs that we charge to get into our market to give them an incentive to do what they don't want to do because of cost factors.

Dr. TIERNEY. Could I add to this?

Just one sec, I spent a lot of time on China's energy outlook.

China is actually an unsung story on a lot of innovations and I think that the part, the main point of what I'm about to say is that the U.S. needs to continue to advance technology leadership so that we don't get our——

Senator MANCHIN. I think Dr. Birol said basically if we don't do something, basically——

Dr. TIERNEY. They will.

Senator MANCHIN. We sat on our hands for the last decade and did not do anything——

Dr. MEDLOCK. Well, I will say this, if you look at federal in real dollars. I have a colleague that's actually written about this. He was a former science advisor to the Clinton Administration.

In real dollars, federal R&D spending has been declining for the last 30 years, and that doesn't make any sense.

Dr. TIERNEY. And they are building advanced reactors. They have huge wind construction. They are dealing with the air pollution, tragic air pollution issues associated with their choices.

They are doing a lot, and we need to step it up so that we don't lose to them on these competitive technologies. So, that's a reason——

Senator MANCHIN. They are not using them though.

Dr. TIERNEY. What?

Senator MANCHIN. They are not using them. They are turning off their scrubbers. It is not CO_2 killing people in China.

Dr. TIERNEY. Oh, I know that.

Senator MANCHIN. It is basically particulates.

Dr. TIERNEY. Oh, of course, of course.

Senator MANCHIN. And they are not. So, you know, in that type of a country.

Dr. MEDLOCK. These are bigger issues than just China.

I was just in Seoul, and I had a really interesting meeting at the Ministry of Foreign Affairs with the Director of their Climate and Energy Program. And he said on the worst days, 80 percent of the PM in the atmosphere in Seoul is from Beijing. That's remarkable. So transboundary issues are incredibly important, and that's where governments around the world have to come to——

Senator MANCHIN. The final question I wanted to ask, very quickly because my time is running out, is that basically, regulated versus deregulated states on the PSC, Public Service Commissions, and all that.

We have a regulated state. So basically, energy that we need, we produce, we regulate that. We do not have the market in a rural area. Deregulation has not worked in rural America, I can assure you. We have gotten screwed every time.

I don't know how you all look. And Joe, I know you were in on that. How do you look about regulated versus deregulated? How it is working in the marketplaces? I think you just all said it has not driven down prices. It has not brought more competition in.

Mr. KELLIHER. Retail competition has largely been limited to states that had very high retail rates to begin with. It also was states that typically had large industrial customers and those industrial customers felt like cost properly attributed to residential customers, real people, were being assigned to them. They wanted to flee those costs.

So industrials typically have been the driving force behind retail competition, not surprisingly, they've also been the primary beneficiary. And in many of these states, residential rates are higher from a competitive supplier, the offerings from a competitive supplier, than they are from the regulated utilities. There have also been marketing and fraud investigations of some competitive suppliers in a number of states—New York, Connecticut, Massachusetts, Rhode Island, I think. So there are some questions about the competitive suppliers.

Dr. MEDLOCK. I'll just add one thing to that, real quick.

We recently did a study looking at the Texas situation. And I think it's dangerous to paint with a broad brush, because the introduction of liberalized markets looks different in every single application.

Texas is a case, actually, where retail rates have declined relative to regulated rates. And you actually see side-by-side regulated utilities and competitive enterprise and you've seen successes there, so.

The CHAIRMAN. Thank you, Senator Manchin.

Senator Cortez Masto.

Senator CORTEZ MASTO. Thank you.

Let me follow up with a question that I also asked. Being from a western state, water is very important to us. I am curious, how is the energy sector at large compensating for changes in water availability and the potential declining supply of water? I am curious. I would just open it up to the panel, if this has been a consideration.

And just to put it in perspective, most of the western states, as you may or may not know, we are in drought mode right now. Obviously the utilization of water for everything we do within our communities is scarce but most important for how we move forward with the innovation and this technology.

Nevada is an innovation state. We are moving forward with technology. We have solar, geothermal, some wind, but I am curious if you would touch on that a little bit and whether that has been incorporated into your analysis?

Dr. TIERNEY. The portions of the state where there is either high reliance on hydroelectric power, where snowpacks and their decline and drought conditions are really affecting it, you know, that is

your part of the world, that's my part of the world. And those utilities are quite mindful of that.

Some of the implications are that they have to add other, thinking about adding other supplies to make up for reserves and contingencies.

But additionally, water is also used for cooling technologies for power plants and as a result of that we have a situation in Texas where the water in the rivers was so hot they couldn't take the outflow from a power plant and they couldn't operate the power plants.

So there are a variety of different kinds of effects on this, and that is affecting the need to add for a robust mixed supply of resources. It keeps being the theme.

Senator CORTEZ MASTO. Okay. Thank you.

The CHAIRMAN. Senator King.

[Senator King shook his head no.]

The CHAIRMAN. I wanted to ask a question of you, Mr. Kelliher, because I think it is notable what we have seen with a number of utilities that have voluntarily pledged to reduce their emissions. Xcel Energy committed to reducing 100 percent of carbon dioxide emissions by 2050. Your company, NextEra's Florida Power and Light, has committed to reducing over 65 percent. And notably, these have been done in the absence of any federal mandates. In your testimony you cite—you just say driven by market fundamentals.

I guess the question to ask is, you have some leaders that have stepped up and have taken these positions. We are seeing more coming on. But we have had a little bit of discussion about the benefits of tax credits moving forward, different policy initiatives. The whole debate regarding mandates versus incentives, I think, is an important part of this discussion.

And as much as we would like to think that technology is going to be driven by all of these brilliant grandkids and when I have a grandkid, he or she will also be in this mix, but the reality is that we can influence it in different ways here.

And one of the ways that I certainly hope we don't go is by picking the winners and losers, because I think we always pick wrong and I don't think that is the way to advance. That is why I love using Alaska as this model of innovation because it is just, kind of like, go out there and figure it out. You have some duct tape and some imagination, and we are making some great pioneering things happen.

But what incentives do work? I think we have heard tax credits. Mr. Kelliher, if you can speak to what more we might be able to do to see more utilities moving forward voluntarily and then this whole discussion of mandate versus incentives.

I would like to have that as part of our closeout here.

Mr. KELLIHER. Sure.

First of all, I think utilities really are moving forward, and we're helping them because we will develop projects and typically sell to the local utility.

But many utilities are actually buying more than they're required to by the state renewable portfolio standard. They're doing it because it makes economic sense. The price has declined so much

that it's not something being forced upon them. They're volunteering to buy that additional increment.

And it's also because their customers want clean energy. So, the customers are asking for it.

And in terms of general approach, assuming there's some consensus that develops around carbon policy, what's the conceptual way to attack it?

And one is to embrace a certain technology or fuel, but that always makes me think of the Fuel Use Act of 1978, probably the most embarrassing federal law ever enacted where Congress deemed that we were running out of natural gas and so, therefore, we had to outlaw the use of natural gas for electricity generation. Today natural gas is the number one source of our electricity generation.

So blessing a technology is assuming perfect, a Cassandra-like ability to see into the future.

But also, like laying out a number, I also don't think is the right approach. That makes me think of like the Waxman-Markey bill from a few years ago. You start with a number. What's the basis of the number?

The Bingaman bill from a few years ago, around the same time of Waxman-Markey, I thought, was a sounder approach. What it was saying there was well, what are the actions that will lower carbon emissions, what are the activities that will result in lower emissions that we want to incent, we want to encourage, we want to lower barriers to? And the Bingaman bill didn't have a number, didn't have a percentage target but it embraced a suite of policies that would have the effect of lowering carbon emissions. I just think conceptually that's a better way to go, typically if it's a technology neutral approach.

And I do like the state renewable energy standards. They're sometimes criticized as a mandate. But one thing they did that was very effective that isn't really recognized is they promoted competition between and among renewable technologies and between suppliers. So it worked differently than PURPA with qualifying facilities. And the end result is the lower cost technologies have prevailed over time. Solar collector, for example, really isn't being built anymore because solar PV proved to be just much more cost-effective.

So, sort of, encouraging competition among technologies not blessing a technology, not laying out a number, I just think is, you know, encouraging investment, encouraging activity, lowering barriers. That, conceptually, is just—I think it would be a more successful approach.

The CHAIRMAN. Mr. Schutt, what would it mean on the ground? More incentive? More mandate? I am thinking you are not going to say mandate.

Mr. SCHUTT. I agree with Mr. Kelliher.

I think incentives work better than mandates and technology agnostic incentives and policies help if the end objective is to reduce carbon emissions and other emissions than what does it matter what the technology is.

There are a number of different areas within this complex sector where you could theoretically achieve better efficiencies or con-

servation or, you know, primary production from new and potentially unknown technologies.

So looking out into the future 10 or 20 years is very, very hard and, you know, durable tax policy with good incentives and that is agnostic to technologies is the preferred choice, I think.

The CHAIRMAN. Dr. Tierney?

Dr. TIERNEY. There's just two things I would add to the conversation on your question.

One of them is I have not heard anyone yet talk about the, what I'll call preciousness of existing nuclear technologies such that if we lose the existing fleet of nuclear reactors quickly, we will be, we are going to raise electricity rates and we are going to have terrible problems from a greenhouse gas replacement.

The CHAIRMAN. I agree. I am glad you mentioned that.

Dr. TIERNEY. The second thing is I'm thinking of the CEO of Xcel Energy when he announced his 100 percent aspirations for zero carbon supply in 2050. He did say, I don't know how I'm going to get there yet and he needs R&D. So I'm not speaking for him, but I heard him say that. And for this Committee, I think that's an important message.

The CHAIRMAN. Yes, you can talk about it, but you can't get there unless you have the R&D and then the commercialization.

Dr. Medlock?

Dr. MEDLOCK. So you could talk about incentives which, I think, are generally a better approach than mandates but you should also, I think, be open to disincentives. And I know tax is a three-letter word, but if you're trying to alter the economic landscape, typically one of the best ways to do that is through pricing mechanisms and tax is actually a viable approach.

Unfortunately, we tend to want to, in various ways, subsidize all sorts of things from upstream oil and gas all the way through to renewables. And one of the things that I think would be a really interesting experiment to run is to remove all of those subsidies and see what wins. I know that's sort of a——

The CHAIRMAN. That is neutral.

Dr. MEDLOCK. ——pie in the sky wish, right? But I think it would be interesting.

The CHAIRMAN. Ms. Jacobson?

Ms. JACOBSON. Thank you.

I guess I'll just end, you know, agreeing with a lot of what has been said here.

I think what's key for all of you is building bipartisan, durable policies that the market can invest on. And there's tremendous leadership and knowledge in this Committee to offer the full Congress and the Administration to move forward because if these policies are not cost-effective, and that, kind of, gets to your question about mandates or incentives, and incentive or a mandate that is providing economic harm, you know, is going to be rejected over time. And then we're back where we are now, to some degree.

And I actually shouldn't say that because I've been so impressed over the past several months seeing the conversation on climate change. And this hearing today is just another example of bipartisan interest and a refreshed, robust serious conversation on what the Federal Government, aligned with other policymakers in the

private sector can do. And so, again, back to this question of, you know, mandates or incentives? Whatever is chosen needs to leverage private sector activity.

We're at this moment where we're seeing tremendous leadership by the private sector capturing the benefits of RD&D for low cost electricity. And so, now that we've seen this progress, even just looking at the past decade, how do we take that to the next level?

And so, back to where we started with research, development and deployment in all these areas that we seek. There's so much that we can do. And maybe we build out from there. But we shouldn't take for granted the fact that we've had strong RD&D budgets. It wouldn't happen without your leadership here.

You know, we were in a very different position, maybe, four to six years ago. And now, as we've heard over and over, we need to do much more.

So, I just don't want us to take for granted the current political environment and bipartisan support that we've had for RD&D and now how do we accelerate it as we move through this Congress and the years ahead.

And then the last thing I would say because it was kind of incomplete, I mean there is an opportunity on incentives, on tax policy. There's a number of energy efficiency tax credits, tax credits for non-wind PTC technologies like hydro, geothermal, biomass, waste to energy. There are other tax incentives that have, you know, basically moved off the books in the last couple of years while other industries have benefited from stable tax environments.

We need to rectify that in the very, very short-term and Chairman Grassley and Senator Wyden introduced a bill last week that would extend. So, it's not just energy related. It's across the economy.

But there are many energy incentives that need to be extended immediately while we look toward policies in the future.

The CHAIRMAN. Well, I appreciate the contributions from each of you and particularly, Ms. Jacobson, when you remind us that this Committee has a role.

Clearly the effort here is to get a bipartisan conversation going. I think that the rhetoric surrounding the issue of climate and climate change can be so heated and so animated and so oftentimes just a very toxic discussion that you cannot get to focusing on the solutions, on where we are going in a positive way on what it is that we should be focused on which is what are the technologies either or today or that we will be coming up with tomorrow and the day following. I think that is the role that we clearly play within this Committee is leading and leaning in on these technologies.

Senator Manchin, he just could not tear himself away from the Committee.

Senator MANCHIN. I have a group of fellow West Virginians in the anteroom right here. We are working on and talking about energy and the effects of energy.

Let me just say that the hearing that we had today, and I want to thank Chairperson Murkowski because we talked about this. No one would have expected her and I coming from the largest producing states of fossil, coal, and natural gas in my state, the

amount of oil that we rely on from Texas—from Alaska. I know, Texas, that was a mistake.

[Laughter.]

The CHAIRMAN. You are talking about that small state.

Senator MANCHIN. That little state down south.

Anyway, so for us to be able to say, listen, we are all in this together.

The thing I always felt was wrong in the tax policies and all these incentives and Dr. Medlock, you mentioned, yes, they could just wipe the slate clean. Let's find out who survives.

I understand trying to help a developing or a maturing industry. I understand that.

I heard my father one time and people, my grandfather especially, they used to give credit and help people. He had a little grocery store. And he told a guy one time, the guy said, Papa, can you carry me for a while? And he said, Honey, your mother already carried you for nine months. So he was trying to say, when is enough, enough? Okay? We cannot wean ourselves off in America. We just don't whether it is on food stocks or whatever it is. The thing about it is we are shifting a little bit right now. We are not weaning away from fossil. We are shifting the fossil utilization more to gas now than we have been. And I think, Joe, you mentioned that and showed we almost doubled.

With that, the concern I have because we have an ocean of gas under us in West Virginia, an ocean of gas and it is coming on strong all the time. We have not even tapped into Rogersville yet. We are still in Marcellus and Utica, and it is going to come on even stronger.

But I am concerned that they are taking this for granted, because there is so much supply of that left that they are not looking at how do we protect our drilling? How do we basically capture our methane? How do we transport safely? How do we make sure that it is not interruptible by sabotage?

Because it is not, it is not a baseload fuel if you look at the interruption that can be caused from the pipelines to the storage to, basically, our pump stations which can freeze up in adverse inclement weather. All these things have to be considered.

The other thing I want to tell all of my friends who believe that we can switch immediately. I said that if you are saying that renewables are 18 percent, then tell me what five hours of the day you want your electricity or your energy? As long as we come to the facts that we have to have an all-in energy policy and transition ourselves into a much better place.

The other thing I wanted to say was policy under, there was a previous president and he and I had very lively conversations. I said, if you are going to change your energy policy that it might not be as realistic of what we are dealing with in demands we have on the energy sector, can't you at least use your credits in states that have lost a tremendous amount of energy jobs, traditional energy jobs whether it is going to be oil production, whether it is going to be in coal production, whatever? Because the tax credits should basically leave nobody behind. If we are transitioning to a new fuel or a new energy provider, then you should not leave the people behind. Because I guarantee you, and I have said this, a

coal miner will build you the best darn windmill you have ever seen. They will build you the best solar panels. They survived underground for hundreds of years. They know what to do, and they are all experts in their fields. And this is what we have not done well in these policies.

So the only thing I would say, we are going to rely on you a good bit in this Committee, I would assume. This is just the beginning. It is not the ending, one and done. This is something we have to face. What we have to do is make sure those people who believe that we can switch immediately. I have not heard one testimony from a professional that this ten-year cycle can happen. You can be decarbonized in ten years. Well, you can decarbonize it, reduce your carbon footprint by the technologies through research and development which we have not done for the last ten years.

The only thing I would say is I hope that we are keeping our eye on the ball as we move to different sources of energy and that we are doing it in the cleanest fashion and using the technology that the rest of the world should be following because right now, they are not. And unless we use the whole carrot and stick mentality, what is in it for them if they do this, even though they don't have an incentive to do it, other than we want to be in our market. They want to be, basically, open to our markets in a much more advantageous way. I think they will be more—especially India right now, I worry about them because I know how hard they are coming on strong with more power plants, I think coal-fired plants, than anyplace in the world—I think that could be accurate. And they are doing it with less pollution controls than anyplace else in the world. And we have the technology to prevent that from happening.

I just want to say, Madam Chairman, thank you again. This is so well timed and I think it would lead to the Energy and Natural Resources Committee leading the way and showing that we can, coming from Alaska and West Virginia, we are very much inclined to make the changes that have to be made, but also in a realistic way and pragmatic way.

Thank you.

The CHAIRMAN. Thank you, Senator Manchin.

I think, as Senator Manchin has just reminded us, that this is an issue or these are issue spaces that this Committee will occupy within our jurisdiction recognizing that, again, it is shared by many of the committees that are here. But I do think this is one of the exciting areas where we can truly make a difference for our nation's economy, for our nation's environment and, really, for our nation's health. And we do it through really smart, innovative people creating good jobs. There are a lot of wins to have, there are a lot of challenges, but we have a good opportunity within this Committee to help shine a spotlight on it.

So thank you all, ladies and gentlemen, for your time this morning to appear before us on this panel but also for the work that you have done over the decades in these important spaces.

With that, the Committee stands adjourned.

[Whereupon, at 12:12 p.m. the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

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Questions from Chairman Lisa Murkowski

Question 1: In your written testimony, you mention the eight nuclear reactors your company operates across the country. You discuss them as clean, emissions-free power generators. As we look across the nation at the nuclear reactors slated for retirement before the end of their operating licenses, including your Duane Arnold nuclear plant in Iowa, I am concerned about the long-term consequences.

- I understand that the costs of maintaining a nuclear reactor on standby are unmanageable, so when these reactors close, they will not reopen. Do you agree with that assessment?

Answer: A number of nuclear reactors have restarted after being shut down for a period of years, both in the U.S. and other countries. For example, the Peach Bottom reactors in Pennsylvania and Millstone 2 in Connecticut were both ordered shutdown by the U.S. Nuclear Regulatory Commission (NRC) for safety reasons, but resumed operations after lengthy shutdowns. A large number of Japanese reactors were ordered shutdown after the Fukushima incident in 2011, some were permanently closed, but nine reactors have restarted after being in standby condition for up to seven years and 12 more reactors are seeking to resume operation after being on standby for even longer. So standby costs are not unmanageable. However, none of the restarted reactors referenced above were placed in standby for economic reasons, they were temporarily shut down for safety reasons with the expectation they would resume operation after safety issues were resolved. An uneconomic U.S. nuclear reactor would likely only be placed in standby condition rather than closed if the owner had confidence natural gas prices and wholesale prices would rise to the point where the reactor would become profitable again, a prospect that may be remote.

- Are you concerned about the long-term consequences if our current nuclear fleet shrinks considerably?

Answer: From an electric reliability perspective, I do not have concerns about the retirement of uneconomic nuclear reactors not needed for reliability. Analysis suggests that the retirement of nuclear reactors beyond expected levels can be accommodated by new entry with no effect on reliability. It is important to recognize that a majority of U.S. commercial nuclear reactors are ratebased utility projects dedicated to serving retail customers that are not directly exposed to low wholesale power prices and face minimal risk of premature retirement. Regarding non-utility or competitive reactors, many are profitable, some are receiving state subsidies for job retention and other purposes, and uneconomic reactors needed for reliability are eligible for Reliability-Must-Run cost based agreements. In short, the nuclear reactors at risk of retirement are competitive projects that are both uneconomic and not needed for reliability. That is a modest number of reactors. A recent report by the PJM independent market monitor estimated that only three of the 18 nuclear plants in PJM would not cover their annual avoidable costs over the next three years (2019 through 2021).

- If so, what are the ramifications?

Answer: I do not believe there are important ramifications from retirement of uneconomic nuclear plants not needed for reliability, given the robust entry of efficient gas generation and solar and wind generation. As noted above, RTOs have the ability to enter into Reliability-Must-Run cost based agreements with

uneconomic nuclear reactors needed for reliability and some states are subsidizing uneconomic nuclear reactors for job retention and other purposes, so the units at risk of retirement generally are uneconomic competitive nuclear reactors not needed for reliability. From the perspective of carbon emissions, the retirement of uneconomic nuclear reactors could make it more difficult to reach any target set by future national policy, but larger wind and solar development could offset those retirements.

Question 2: While concerned about premature closures in today's U.S. nuclear fleet, I am bullish on the future of advanced reactors. Last week, Dr. Birol of the International Energy Agency and I discussed the importance of re-establishing U.S. global leadership in nuclear to ensure that advanced reactors are designed and deployed here. In your written testimony, you talk about the important government support that brought wind and solar technologies to market and brought down the cost curve. I have been working on policies that will do the same for advanced nuclear technologies like small modular reactors. These advanced reactors may provide different value streams like high-temperature heat for manufacturing or off-grid power to remote communities like those in Alaska. They will also provide power to the grid. As you look forward to these next-generation technologies, what kind of value will advanced reactors provide and can you see a company like NextEra purchasing some of these advanced reactors?

Answer: In my view, the key to adoption of advanced reactors will be primarily economics, whether the cost of generating electricity from advanced reactors compares favorably with other alternatives such as efficient gas generation and wind and solar generation. If the economics are not competitive, I would not expect to see significant commercial deployment of advanced reactor technologies. Other challenges facing advanced reactors include uncertainties associated with NRC licensing of these unproven designs, the length of reactor construction, and the lack of a track record of operational performance and cost.

Question 3: In order to see increased adoption of carbon capture, we know we need to make some important breakthroughs in technology and cost.

- What role will carbon capture play in our clean energy future?

Answer: Carbon capture could play an important role in our clean energy future if the federal government adopts a carbon policy that puts a price on carbon. I see no realistic scenario where the United States stops using fossil fuels for electricity generation in the near future, and the U.S. Energy Information Administration (EIA) projects that coal and natural gas will remain significant components of U.S. electricity supply mix through 2050. The same is true for the electricity supply mix outside the U.S. As a result, the IPCC and other organizations have concluded carbon capture will be necessary. In the absence of a federal policy, carbon capture would likely play a much smaller role in the U.S., even with the tax credits recently enacted by Congress.

- What are the things that Congress can do to accelerate the development of carbon capture technology?

Answer: Congress has already recently enacted a tax credit to stimulate carbon capture. Congress could also examine DOE research and development programs relating to carbon capture technology, assess the effectiveness of these programs, and undertake program reforms and set funding levels accordingly.

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Congress could also address the regulatory and legal challenges to using carbon in enhanced oil recovery and storing carbon in large-scale geologic sequestration.

Question 4: In your written testimony you point out that new Environmental Protection Agency regulations were "only a secondary factor" in the shift toward cleaner sources of electricity generation. You also note shale gas as the primary factor in moving to cleaner electricity, but as you know, the availability of gas depends directly on permits issued by government, especially the Federal Energy Regulatory Commission, to build needed infrastructure to get that gas to a place where it is needed.

- To what extent is the question about markets vs. regulators a chicken and egg problem? That is, markets cannot be efficient without regulators who support efficiency, yet on the other side, regulators cannot approve infrastructure unless they believe that markets are the most efficient way to organize the energy industry.

Answer: I agree there is a "chicken and egg" relationship between energy markets and infrastructure. Electricity markets cannot function properly without adequate infrastructure, meaning adequate generation and a robust grid, and a competitive market in turn promotes development of a robust infrastructure to support those markets. Poor infrastructure development generally impedes competitive markets and results in higher costs.

- Without an industry that believes in the power of market solutions, coupled with regulators who also believe in the power of market solutions, how would we be able to make the energy industry cleaner and more efficient?

Answer: Without market solutions, the only way to make the energy industry cleaner and more efficient is through direct federal and state environmental "command-and-control" regulation. This would likely cost substantially more and produce poorer results than a market approach that put a price on carbon.

Question 5: Clearly the power sector is not the only industry contending with emissions. What other sectors of the economy should Congress focus on to reduce overall emissions?

Answer: The U.S. electricity sector no longer has the largest carbon dioxide emissions. Since 2015, the transportation sector has been the largest carbon emitter, followed by the electricity sector and industrial sector. Moreover, transportation sector emissions have been rising every year since 2012, while electricity and industrial sector emissions have been declining. The electricity sector can enable emissions reduction in the transportation sector through electrification where feasible and cost-effective, such as through electric vehicle charging stations. If the federal government adopts a carbon policy Congress should consider actions to reduce emissions from these three principal sectors.

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Questions from Ranking Member Joe Manchin III

Question 1: Dr. Tierney pointed out in her testimony that, although there was an increase in carbon emissions from 2017 to 2018, overall, power sector emissions declined substantially over the past decade, with electricity generation and use remaining relatively flat. Carbon dioxide declined by about 28 percent from 2005 through 2017.

What technologies have you seen in practice that have shown the most success in emission reductions so far?

Answer: The technologies that have made the greatest contributions to the reductions in carbon emissions since 2005 are the advances in natural gas production techniques, the improvements in the efficiency of new natural gas generation, and the improvements in the cost and output of wind and solar technologies.

What technologies have you seen at DOE and the labs that have a great deal of promise for providing reliable energy with a lower emissions profile?

Answer: DOE has invested in energy storage and has an ambitious R&D program for long duration batteries. Although storage is largely neutral on emissions, it can allow grid operators to better manage the grid and integrate more renewables. DOE is also investing in grid modernization technologies.

What can Congress do to foster commercialization of these innovative power sources?

Answer: The most important action Congress could take to accelerate deployment of storage is to clarify that storage co-located with wind generation facilities and storage in standalone operation independent of solar or wind generation both qualify for the existing investment tax credit.

Question 2: Many of the witnesses the Senate Committee on Energy and Natural Resources has heard from so far this year, including Linda Capuano of the Energy Information Administration and Dr. Ernie Moniz, have indicated that fossil fuels are going to be part of the global generation mix for decades to come. Dr. Birol from the International Energy Agency (IEA) echoed that the hearing on February 28, 2019. All three of the scenarios the IEA examined included fossil fuels, including coal, being used through 2040. It seems to me that while your company is expanding dramatically into wind power, your investments in natural gas up and down the value chain reflect agreement with the conclusion that fossil fuels will be needed for some time.

How is NextEra Energy looking toward the future with respect to investing in R&D to burn natural gas cleaner in the future?

Answer: NextEra Energy is a technology consumer and does not directly invest in R&D, and gas combined cycle technology is mature, so recent efficiency improvements have largely come from the vendors themselves. However, FPL has placed a greater focus on modernizing and improving the efficiency of its gas generation fleet than perhaps any other generator in the country, and our gas generation plants in Florida are among the most efficient in the U.S.

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Do you agree carbon capture needs to be part of what utilities are considering working with the federal government on?

Answer: Carbon capture could play an important role in our clean energy future if the federal government adopts a carbon policy that puts a price on carbon. I see no realistic scenario where the United States stops using fossil fuels for electricity generation in the foreseeable future and the U.S. Energy Information Administration projects that coal and natural gas will both remain significant components of our electricity supply mix through 2050. The same is true for the electricity supply mix outside the U.S. As a result, the IPCC and other organizations have concluded carbon capture will be necessary. In the absence of a federal policy, carbon capture would likely play a much smaller role in the U.S., even with the tax credits recently enacted by Congress.

Question 3: Your testimony outlined a narrative about the retirement of "inefficient" power plants. While I certainly agree that the onset of the shale revolution in natural gas changed the markets a great deal, it seems to me that we still have problems getting natural gas into the northeast and we still need reliable baseload generation when extreme cold hits and natural gas prices spike in New England and New York. Additionally, natural gas is a fossil fuel. So, as emissions in the power sector are discussed, I think it's important to note that natural gas still requires additional infrastructure build-out and it is a fossil fuel which developing nations are using more and more of.

Therefore, I'd be interested in your perspective on carbon capture for natural gas. Is NextEra looking into this as an R&D priority?

Answer: The use of carbon capture on natural gas generation facilities is less developed than with coal generation, and to my knowledge there is only one current 50 MW demonstration project. Carbon capture from gas generation facilities is more difficult and more expensive than from coal generation because the concentration of carbon from the combustion of natural gas is much less than the concentration from the combustion of coal. I believe there is a need for more research in this area.

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Question from Senator Debbie Stabenow

Question: As this Committee assesses our country's energy policy, we are at a pivotal time to capitalize on clean and renewable generation. Could you speak to the role that investments in transmission capacity can play in helping spur the development of these resources, and how Congress can help accelerate these infrastructure investments?

Answer: Robust transmission investment is necessary to build out a grid that can deliver clean energy to Americans. Our power grid was built in the past to deliver yesterday's electricity supply, and as our electricity supply rapidly transitions we will need a different grid. With the exception of the federal electric utilities like the Tennessee Valley Authority and the federal power marketing administrations, grid investments do not require federal expenditures. The interstate power system has been largely developed by regulated public utilities. There has been a robust level of investment in transmission in recent years, and continued investment can be expected as long as FERC and state public utility commissions provide a reasonable return. FERC recently initiated a proceeding to examine whether its policies governing return on equity encourage adequate investment.

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Questions from Senator Mazie K. Hirono

Question 1: In your testimony, you described some of the renewable energy and energy storage projects that NextEra Energy is pursuing. Some utilities around the country have concluded it is cheaper to replace fossil fuel plants with combinations of renewable power, energy storage, and demand management. Is NextEra expecting lower costs for customers from its recent renewable energy, energy storage, and efficiency/demand management projects, and, if so, could you please describe the savings? If not, does the company have a forecast of when such projects would offer lower costs compared to fossil- and nuclear-powered plants?

Answer: There are great opportunities to lower cost and improve performance through modernization of power generation. For years, our subsidiary Florida Power & Light has replaced older, fossil generation facilities with modern, efficient generation with much lower fuel and operating costs, delivering $10 billion in cumulative in fuel cost savings to customers during 2002-2018. Florida Power & Light recently announced plans to build the world's largest combined solar-storage project, replacing two aging gas generation facilities. Onshore wind and solar PV projects already have lower costs than coal and nuclear facilities. Storage costs have declined to the point where storage projects may displace conventional gas peaking units, and a combined solar PV-storage project can produce energy at a lower cost and with better performance than new nuclear generation, with much lower regulatory risk and far superior cost certainty.

Question 2: Under federal and state law, electric utilities have an obligation to keep rates just and reasonable, and maintain the reliability of their systems. Recognizing the preference of electric utilities to know how a new technology fully works before trusting it on their systems, do you think the Department of Energy should offer competitive grants to projects to demonstrate new technologies to improve the performance of the distribution system in the transitioning electric markets you described in your testimony? If so, are there particular challenges you would suggest the Department of Energy focus on to help modernize the distribution system (e.g., integration and management of electric vehicles, intelligent loads, energy storage, microgrids, etc.)?

Answer: There are different types of incentives, and the type of incentive that will be more effective demonstrating or accelerating deployment of new technologies can vary, depending on circumstances such as how commercially ready the technology is. For example, grants were very effective in accelerating smart meter deployment and tax credits were highly effective in expanding renewable energy generation and improving wind and solar generation technology.

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Questions from Senator John Hoeven

Question 1: When it comes to enhancing U.S. energy infrastructure, you believe that a more robust power grid and interstate pipeline network is critical. A robust CO_2 pipeline system could be a critical piece in linking the capture of CO_2 from industrial power plants with its productive use in oilfields and secure underground storage. As of 2015, only 4 percent of crude oil production came from enhanced oil recovery, but this is projected to increase. This infrastructure has the dual purpose of being both economically advantageous and reducing greenhouse gas (GHG) emissions. Will you speak to how enhanced oil recovery and CO_2 pipeline infrastructure could contribute to more robust energy infrastructure?

Answer: My understanding is that enhanced oil recovery is projected to account for 7% of U.S. crude oil production by 2030, so carbon use for that purpose is increasing. However, the carbon pipeline network is very limited, especially when compared to the extensive oil and natural gas pipeline networks. The carbon pipeline network is about 4,500 miles, compared to the interstate gas pipeline network of over 300,000 miles. If a federal carbon policy is established, it may be necessary to expand this system to support continued use of coal and natural gas in U.S. electric generation and increased use of enhanced oil recovery. Carbon pipelines and storage are sited at the state level, there is no federal authority to site these projects, and not all states have addressed carbon pipeline and storage siting. A federal carbon policy should consider whether there is a need for an expanded carbon pipeline and storage network and whether Congress should provide for federal siting to facilitate development of a network.

Question 2: February was a record cold month for my home state and we saw time and again where wind turbines had to be shut down because of extreme temperatures and coal and gas were relied-on to provide power. Many utilities participate in regional competitive markets, where in many cases the wholesale price of power is driven lower by the renewable Production Tax Credit and other factors. How do you propose that we address this issue to ensure that utilities can afford operating generation that is needed when the wind isn't blowing and sun isn't shining, especially when they do not receive compensation for the costs incurred to remain on standby?

Answer: With respect to the effect of wind generation on wholesale power prices in the RTO markets, the effect is highly overstated. The 2017 DOE Staff Report on Electricity Markets and Reliability noted that negative bidding is not limited to wind generation and conventional generation such as coal and nuclear generation may bid negative in certain periods because of operational inflexibility. Nonetheless, negative bidding rarely affects wholesale power prices in RTO markets. The DOE report concluded negative pricing events are rare, and "have had almost no impact on annual average day-ahead or real-time wholesale electricity prices" and other recent analysis concluded negative bidding set day-ahead prices in the three FERC RTOs with the highest wind penetration levels in only 3 or fewer out of every 1,000 hours. The record is clear that the primary causes of low wholesale power prices are increased gas production, lower gas prices, and lower electricity demand.

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Questions from Chairman Lisa Murkowski

Question 1: As you know, it has taken a long time to secure enough funding to allow Newtok to continue their relocation efforts to the new village site of Mertarvik. "Whole-community relocation" is a term that most are probably unaware of, but it is alarmingly relevant in Alaska. Your written testimony notes that there are three other communities besides Newtok that immediately need to move the entire community to "escape life-threatening conditions." What are some of the lessons from the Newtok relocation project that we can apply to the next whole-community relocations?

Answer: The list of critically threatened communities in Alaska, while static in formal documents, is dynamic in the real and changing world. That official list of Alaska communities derives from a 2009 GAO study. The communities facing the need to immediately relocate the entire community include Newtok, Kivalina, Shishmaref and Shaktoolik.[1] There are an additional eight communities facing the need to partially move or to more gradually migrate the entire community. These additional eight threatened communities are: Teller, Golovin, Unalakleet, Nulato, Koyukuk, Huslia, Hughes and Allakaket. An additional nineteen communities are listed as imminently threatened. The data for these flood, storm surge and erosion threats come primarily from to GAO reports dated 2003 and 2009. The reality is that this situation is more dynamic and severe than the official 2009 list suggests—exacerbated by the fact that a decade of accelerating change has now passed since the last official update.

The community of Napakiak, located on the lower Kuskokwim River in Southwest Alaska, is officially listed among the 31 imminently threatened communities but it is not officially on the list of communities that face total or partial community relocation. In fact, Napakiak has experienced significant and recurrent riverine erosion and storm surge. Vital community infrastructure including community fuel storage tanks and the village school are now less than 150 feet from eroding into the river, and recent storm events have eroded as much as 80 feet in one event. As of a report dated May 2018, the entire community of Napakiak will need to be relocated due to riverine erosion, storm surge and permafrost degradation. A storm event last spring on May 12-13, 2018 caused 20 to 30 feet of shoreline erosion threatening the armory and the school's fuel tank farm. The community has been moving threatened buildings back and away from the Kuskokwim River on its own for over a decade. But now the River threatens Napakiak's school, a building too large to move and too central to community life to lose without replacement.

Napakiak's situation encapsulates the reality of life in rural Alaska communities threatened by climate change impacts: they quietly and practically adapt on their own, moving buildings, rebuilding roads and lost infrastructure, until the impacts exceed their local capacity. And then they ask for help from the federal and state governments and wait and hope that help arrives in time.

The Mertarvik relocation project is the vanguard project relocating an entire community in rural Alaska due to the threats of climate change impacts. That project is underway as preliminary community infrastructure and some homes have been built at the Mertarvik site as the entire community of Newtok prepares to move there in phases. ANTHC has been involved with the Mertarvik relocation project, and

[1] Federal Emergency Management Agency, Alaska Risk MAP: Assisting Alaska Native Villages. http://dcced.maps.arcgis.com visited March 19, 2019.

was awarded the function of project manager by the Denali Commission in the spring of 2018. There are a number of lessons learned from the Newtok-to-Mertarvik relocation project to-date.

Accelerating impacts. The impacts of climate change in Alaska are accelerating due to a variety of factors including thawing permafrost, loss of seasonal sea ice and increased rates of riverine and coastal erosion. Impacts that used to be viewed as foreseeable and oncoming years to decades in the future, are now potentially only years away. These now rapidly approaching impacts highlight the need to act expeditiously and strategically in addressing future community adaptation projects.

Shorten the planning cycle. The planning cycle for the Newtok-to-Mertarvik relocation began at some level in 1983, with a serious hastening of the threat in 1996. The planning continued until the first significant physical activity at the Mertarvik site began in 2011. This multi-year effort to seek community input, coordinate relevant federal and state agencies, select a relocation site, begin the community layout and design, secure preliminary funding and plan the logistics of the move is understandable given Mertarvik's vanguard role. But it is too long a planning cycle for any additional community relocation (total or partial) or critical community infrastructure relocation or replacement. Experience and better coordination require discipline and diligence but can substantially shorten the planning cycle for future community adaptation projects. Utilizing the Denali Commission and ANTHC to assist in planning future projects will leverage expertise and experience to shorten the planning cycle.

Funding coordination. All public money comes attached to different application and eligibility criteria, use restrictions, timing for disbursement (i.e. federal vs. state fiscal year cycles) and reporting requirements. Coordinating and consolidating disparate funding streams through the Denali Commission—a joint federal and state agency—greatly assists in focusing community adaptation projects on substantive activities instead of filling out forms to check the boxes attached to the funding.

Expertise in rural operations. Designing, constructing and operating community housing and infrastructure in rural Alaska comprises its own subspecialty. Rural Alaska is littered with projects that underperformed, from minor to disastrous underperformance, due to a lack of expertise in translating what may work fine in an urban or road-connected community into a rural and isolated community. Coordinating design and project management with the Denali Commission and ANTHC significantly mitigates the risk of future community adaption projects.

Coordination. Coordination among the variety of necessary stakeholders, funders, regional and local leadership, and regulatory agencies in partial and total community relocation efforts ranks as the most critical factor in assuring timeliness, success and efficiency of the public investment. Coordinating the various funding streams, on-the-ground activities, planning and permitting, stakeholder engagement and reporting functions requires capacity, expertise and attention. Directing funding for future community adaptation projects through the Denali Commission will assure that coordination occurs.

Constructability. Virtually any design that can be engineered can be built. Unfortunately, poor building designs and community layouts lead to higher construction and life-cycle operational costs. Projects in rural Alaska's already high-cost environment can afford neither. ANTHC provides an expertise in community infrastructure constructability for rural Alaska. Ensuring a role for it or another similarly

expert public entity to ensure constructability is addressed for future community adaptation projects is a critical step in ensuring the prudent use of scarce public funds.

Efficiency. While construction costs are high, the life-cycle operational costs to heat and maintain built structures far outweigh construction costs in the harsh, high-cost environment of rural Alaska. Ensuring energy efficient designs for all built structures must be prioritized for all future community adaptation projects.

Question 2: You highlighted the Denali Commission, the USDA's Rural Alaska Village Grant Program, and the State of Alaska as the primary backers for the Rural Energy Initiative. In ANTHC's experience and from your viewpoint, where can the Department of Energy provide leadership to help Alaska combat the effects of climate change?

Answer: The Department of Energy (DOE) would be most valuable in providing funding and expertise to help investigate and design a new class of modular and relocatable generation that would greatly increase overall system efficiency while providing additional community resiliency to threatened communities. DOE could utilize its capacity and expertise to design, construct, and refine the operations of systems to maximize the efficiency of the whole power system for a remote microgrid while incorporating combined heat and power and high penetration renewable generation. Lessons learned from this area, as applied to systems instrumentation and controls in particular, would potentially have broad applicability to the grid edge of the larger integrated grids in the continental United States.

Question 3: You provide some valuable data points in your written testimony, including that there are more than 160,000 Alaska Native and American Indian people living in Alaska, and that 184 of our traditional Alaska Native communities are right now environmentally threatened to some degree by effects related to climate change. There is no one size fits all approach for Alaska – geography and effects of climate change vary greatly from village to village. It is also difficult to travel from community to community.

Response: We agree with your assessment regarding the reality of rural Alaska and its Alaska Native communities.

- Would you please describe the complex dynamics that exist in rural Alaska when it comes to energy, health, and sanitation issues?

Answer: As noted in the preamble to your question, "the situation" in rural Alaska shares some similarities community-to-community, but the differences are often significant as determined by local and regional factors. Many rural communities are located on the coast or along significant rivers for many historical and practical reasons.
The commonalities include remote location, a lack of public highway access, small community size, high cost and a community location fronting on the coast or along a major river.

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The differences include local soils and topography (including some locations on islands, low coastal spits or coastal barrier islands), local climate (from temperate rain forest to arctic), river versus coast, size, community expertise and resources, locally available high ground or the lack thereof, and other factors.

- How does ANTHC approach its mission with such an immense coordination and communication challenge?

Answer: ANTHC recognizes the need to balance local input and control of important projects in small, rural and remote communities with the realities of the need for technical expertise that are resident in much larger institutions such as ANTHC. In performing this delicate balancing act, ANTHC has become expert at

Coordinator. ANTHC often acts as an expert coordinator for activities to achieve efficiencies and economies of scale that benefit all participants. This coordination also provides for a kind of force multiplier effect. The many streams of funding, lines of technical expertise and interaction with critical stakeholders can overwhelm project participants at local, state and national levels of engagement. ANTHC staff coordinates activities for rural projects, assisting and acting as a hub for all personnel

Aggregator. ANTHC acts as an aggregator of similar projects and project needs to achieve economies of scale in procurement and logistics.

Technical assistance. ANTHC provides expert technical assistance on a state-wide basis for the benefit of communities and regions that otherwise would be unable to have access to such resources.

Question 4: Clearly the power sector is not the only industry contending with emissions. What other sectors of the economy should Congress focus on to reduce overall emissions?

Answer: Space heating and cooling and transportation represent significant areas of energy use and therefore cause emissions directly or indirectly. As such, Congress should investigate areas for improvement within the sectors in addition to the electric power sector.

Questions from Ranking Member Joe Manchin III

Question 1: Dr. Tierney pointed out in her testimony that, although there was an increase in carbon emissions from 2017 to 2018, overall, power sector emissions declined substantially over the past decade, with electricity generation and use remaining relatively flat. Carbon dioxide declined by about 28 percent from 2005 through 2017.

What technologies have you seen in practice that have shown the most success in emission reductions so far?

Answer: The three most important technologies to reduce emissions in the electric sector are efficiency- and conservation-related technologies: LED lighting; high efficiency pumps, fans and compressors for space heating and cooling; and smart controls for building systems.

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An important applied technology in rural Alaska is the use of surplus wind-generated electric power to add thermal energy into the water storage tanks for community water and sewer systems. This use of the community water storage tank as a way to utilize intermittent excess electric power allows communities to install and fully utilize wind turbine generating capacity that would otherwise exceed the purely electric system's native load. By fully utilizing what would otherwise be wasted as surplus electric energy, this technology drives down operating cost of the water and sewer utility by offsetting liquid fuel usage.

Given the strong nexus between energy and water, there is a promising opportunity to explore applied technologies that pair excess renewable generating capacity with beneficial uses within water and wastewater utilities. For instance, an analog applied technology could be increased coordination of off-peak water pumping to community water towers and other elevated storage sites that provide the gravity-fed pressure for community water systems. This applied technology could help make beneficial use of what would otherwise end up being "spilled wind", and other unused generating capacity of renewable energy resources already installed on the grid to perform a necessary, energy-intensive functions for the water utility.

What technologies have you seen at DOE and the labs that have a great deal of promise for providing reliable energy with a lower emissions profile?

Answer: Efficiency- and conservation-related technologies represent the lowest hanging fruit currently available.

What can Congress do to foster commercialization of these innovative power sources?

Answer: Policies that incentive and reward energy efficiency and conservation can provide the incremental incentives for individuals and businesses to more quickly adopt and install in this area.

Question 2: Rural communities, particularly those without access to energy, water, or broadband infrastructure, are disproportionately impacted by climate change. In your testimony you mentioned the high energy requirements of sanitation systems in the Artic and sub-Arctic as a major challenge in rural Alaska, resulting in water and sewer bills that are $80 to $250 per month, or about five times the national average. I understand the Rural Energy Initiative was developed to respond to that cost issue through energy efficiency and renewable energy solutions.

What, if anything, about your Rural Energy Initiative approach is transferable to the lower 48 where many rural communities like those in my home state of West Virginia struggle with utility costs?

Answer: The Rural Energy Initiative's most important and transferrable attribute is its centralized technical assistance model that provides technical expertise, analysis and training to assist local community leaders, plant operators and residents and provide them with the tools they need to efficiently operate and improve their rural utilities. This centralized technical assistance provides a cost-effective solution to supporting and improving the operations of rural utility plants. Such a model provides an effective template for utility operations in any rural area.

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Questions from Chairman Lisa Murkowski

Question 1: Nuclear reactors provide clean, emissions-free power. As we look across the nation at the nuclear reactors slated for retirement before the end of their operating licenses, I am concerned about the long-term consequences.

- I understand that the costs of maintaining a nuclear reactor on standby are unmanageable, so when these reactors close, they will not reopen. Do you agree with that assessment?

  Response from Dr. Tierney:

  I agree with Chairman Murkowski that it not realistic to assume that an owner of an existing nuclear reactor would decide to mothball the unit and continue to maintain it so as to enable it to re-open at some later date. If the going-forward costs of an existing nuclear plant are not expected to be supported by revenues from operating the unit and the owner decides that it is no longer economic to keep it open, then mothballing would be a costly and burdensome enterprise. The latter would involve maintaining security, regulatory licenses, taxes, transmission rights, some staffing levels, and other activities to retain the potential to reopen the plant at some future date. An owner of a nuclear unit—and in particular, an owner of an unregulated "merchant" unit—would have a hard time justifying such expenditures for many years without a revenue stream, and without the expectation of highly attractive financial returns in the future.

- Are you concerned about the long-term consequences if our current nuclear fleet shrinks considerably? If so, what are the ramifications?

  Response from Dr. Tierney:

  Yes. As I have written elsewhere, there are negative cost and air-pollution consequences when a safely operating existing nuclear plant closes.
  - Susan Tierney, "Don't Let Nukes Go Too Fast," *The Hill*, July 15, 2015, https://thehill.com.opinion/op-ed/247858-dont-let-nuke-plants-go-too-fast
  - Susan Tierney, "Is Nuclear Power Vital to Hitting CO2 Emissions Targets? Yes: Renewables Can't Fill the Gap Yet," *Wall Street Journal*, November 11, 2016. https://www.wsj.com/articles/is-nuclear-power-vital-to-hitting-co2-emissions-targets-1479092761;
  - Susan Tierney and Karen Palmer, "Grid Resilience, Generation Portfolios, and National Security," Resources for the Future, May 8, 2018, https://www.resourcesmag.org/common-resources/grid-resilience-generation-portfolios-and-national-security

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I have three concerns regarding the near-term closure of nuclear plants, which today produce power almost around the clock (e.g., 93 percent of hours in 2018), produce one-fifth of total electricity supply to American consumers, and nearly two-thirds of carbon-free power.

- First, from a climate change point of view, whenever a nuclear plant closes in the near term, its output is replaced with electricity generated at plants that run on natural gas, coal, and/or oil, all of which produce carbon emissions. This happens because the solar and wind facilities that exist on the system at the time the nuclear plant retires are already producing as much as electricity as they can (in other words, whenever the wind is blowing and the sun is shining). When a 1200-MW nuclear plant retires, for example, the replacement power from fossil-fueled generating units would lead to carbon emissions equivalent to adding from 0.5-1.0 million cars on the road, depending upon where that plant is located. Replacing both the energy production and capacity of a 1,200-MW nuclear unit with wind and solar alone would require a massive investment, along the lines of 2,000 MW of offshore wind *plus* 1,350 MW of utility-scale solar *plus* storage. (One MW of nuclear capacity produces power over 92 percent of the time, compared to offshore wind (31-51 percent), on-shore wind (11-48 percent), utility-scale solar (15-27 percent), and rooftop solar (12-21 percent). (National Renewable Energy Laboratory, "Annual Technology Baseline," 2018, https://atb.nrel.gov/electricity/2018/summary.html)) The prospects of replacing that much energy and capacity so quickly is daunting, especially since at present, and even after the massive build-up of wind and solar capacity over in the past decade, together they provide 8 percent of the nation's electricity.

- Second, when a nuclear plant retires, power production costs also tend to rise, because more expensive plants will have to be operated to replace the nuclear unit's output. And the investment in zero-carbon generating assets to fully replace the nuclear unit's capacity and energy tend to be more expensive than the going-forward costs of keeping a nuclear unit in operation.

- Finally, there are national security considerations associated with closure of the nation's nuclear fleet: The U.S. has maintained an important seat at the table in international discussions of nuclear technology development, deployment, safety, and security, due to the expertise and capability of American researchers, designers and operators of U.S. nuclear plants. Although not reflected in market prices for power, this capability remains

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important for the U.S.'s strategic interests. Without a set of plants in operations and research/development underway, this capability will be substantially undermined. (Please see the report of the Energy Futures Initiative, "The U.S. Nuclear Energy Enterprise: A Key National Security Enabler," August 2017, https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/59947949f43b55af66b0684b/1502902604749/EFI+nuclear+paper+17+Aug+2017.pdf).

Question 2: While concerned about premature closures in today's U.S. nuclear fleet, I am bullish on the future of advanced reactors. Last week, Dr. Birol of the International Energy Agency and I discussed the importance of re-establishing U.S. global leadership in nuclear to ensure that advanced reactors are designed and deployed here. During the hearing, the important government support that brought wind and solar technologies to market and brought down the cost curve was discussed. I have been working on policies that will do the same for advanced nuclear technologies like small modular reactors. These advanced reactors may provide different value streams like high-temperature heat for manufacturing or off-grid power to remote communities like those in Alaska. They will also provide power to the grid. As you look forward to these next-generation technologies, what kind of value will advanced reactors provide and do you anticipate advanced reactors playing an important role in a lower-emissions economy?

Response from Dr. Tierney:

I agree that the U.S. government has long been a critical actor in supporting the development of next-generation energy technologies, through a combination of RD&D support, tax policy, environmental regulations, technology standards, and policies that underwrite technological development risk. In this context, I think it is important for the U.S. federal government to continue to help support such things as R&D on materials and advanced reactor designs, on manufacturing models for advanced nuclear-reactor components and systems, regulatory reforms to align federal safety reviews with the characteristics of advanced reactor designs, and methods to mitigate risks associated with early stage demonstration projects, among other things.

Question 3: In your written testimony you expressed the importance of the federal government avoiding the adoption of narrow technological solutions to address climate change.

- What technology options do you think can make the biggest difference?

Response from Dr. Tierney:

In addition to continuing to fund research, development and deployment of advanced materials, systems integration, and performance of more efficient wind, solar, biofuels, and to support policy instruments that move them (and

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more energy-efficient devices, equipment and vehicles) into private markets, I think there are at least five areas where the federal government should be involved in supporting RD&D:

- Advanced nuclear technologies and business/manufacturing business models
- Carbon capture and utilization technologies, approaches, and systems
- Storage systems with lengthy energy-storage periods
- Carbon removal technologies, approaches and systems
- Grid modernization investments

- With limited federal funding, where do you see the biggest potential impact being made?

Response from Dr. Tierney:

I encourage the Committee to probe this question with a variety of experts, including those from the Department of Energy, academic institutions, innovative start-up companies, NGOs, the National Academies of Sciences, and others who are working on the technical and non-technical barriers that need to be addressed to help move these advanced technologies forward through research, development, initial deployment, and commercial operations (where warranted).

Question 4: In order to see increased adoption of carbon capture, we know we need to make some important breakthroughs in technology and cost.

- What role will carbon capture play in our clean energy future? What are the things that Congress can do to accelerate the development of carbon capture technology?

Response from Dr. Tierney:

In light of the importance of reducing carbon emissions from domestic and international energy systems, combined with abundance of carbon-intensive fossil fuels in the U.S. and in many parts of the world, it is critically important for the U.S. to continue to explore the technical and non-technical issues associated with carbon capture, utilization and sequestration ("CCUS") technologies, approaches, and approaches. The U.S. government should continue to support, if not expand, the RD&D agenda for a variety of approaches (e.g., technological carbon-capture systems for large and small-scale applications; biological processes for capturing carbon; regulatory regimes to support utilization and sequestration approaches).

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Question 5: In 2014, two Department of Energy labs worked on a report that mapped out a plan for "deep decarbonization" of the nation by reducing greenhouse gases 80 percent by 2050. This plan was part of the "Deep Decarbonization Pathways Project" (DDPP).

- Do you think that we can reduce carbon by 80 percent by 2050?

Response from Dr. Tierney:

This good question goes to the heart of the challenge our nation faces and which is why I appreciative the work that the SENR Committee is undertaking, with Chairman Murkowski's and Senator Manchin's leadership, to explore the electric industry in a changing climate.

I am by nature an optimist and, by professional experience and expertise, a principled pragmatist. So, in response to your question, I say that we must significantly and urgently reduce GHG emissions from our economy, and in order to do so through a combination of political will, policy action, and markets, we must find practical and effective ways to do so.

Based on my own review of the literature on what it might take to achieve deep reductions in carbon and other GHG emissions from the U.S. economy—including the Deep Decarbonization Pathways Project, among dozens of other studies—I understand that it will be much easier to accomplish 'modest' GHG emissions reductions than it will be to reach the levels of emissions reductions (e.g., at least 80 percent reductions by 2050) that are consistent with limiting the worst impacts of climate change.

A number of themes come through this "deep decarbonization" literature that are relevant to this question, including among other things:

- Deeper GHG emission reductions will require a combination of: technological innovations and performance improvements that are likely to be non-linear; continued cost reductions across advanced technologies, materials, and biofuels; significant investment and turnover of capital stock, as well as working through stranded costs in the multiple sectors and systems where fuel-switching and replacement equipment will need to take place; diverse behavioral changes; new business and investment models; new market designs; and many other changes. Addressing such issues will be needed in any of the alternative technological decarbonization pathways explored in the literature.
- Increasing energy productivity through energy efficiency investments and practices is assumed to be an essential part of virtually all deep-

decarbonization strategies. The studies assume efficiency improvement rates that are typically twice to three times historic averages.

- The strong consensus in the literature is that a more diverse portfolio of electric technologies—rather than an energy mix assumed to rely exclusively or nearly entirely on renewable energy technologies with intermittent supply—will likely be more technically feasible and will lead to a lower-cost and low-carbon economy in the United States. Recognizing that not all of the studies explicitly model economic considerations, those that do and that compare the costs of alternative technological pathways conclude that mixed portfolios of energy technologies achieve that outcome at lower cost. This conclusion is driven by a number of factors, including: the need to add much more total capacity in an all-renewables system due to the intermittency of output and low capacity factors, and the need for substantial collateral investment in storage capacity; the very large size of the geographic requirements for siting the large amount of renewable capacity that would be required; the need for storage technologies that are ubiquitous, at scale and capable of discharging across multiple days and/or seasons when wind and solar are less abundant; and the new investment that would be required in substantial additional transmission and distribution capacity, combined with the difficulties of siting the former.

- Finally, the deep-decarbonization literature tends to focus on what outcomes are possible and/or needed (technically and/or technologically), with less attention to *how* those outcomes may be able to unfold. There are many technical, social, economic, institutional, financial, political, and other aspects of the transition that merit substantial continued analysis and attention by researchers and analysts, as well as by public policy makers and electric-system stakeholders.

Together, the studies suggest that an electric system comprised of diverse zero- and low-carbon supplies coupled with an economy that is more reliant on electricity increases the possibility of accomplishing deep decarbonization at lower costs than other approaches. A diverse portfolio would include those technologies that can provide supply on demand as well as those dependent on weather-related and intermittent sources of energy. An important implication of the literature is the combination of both technically available *and* economically accessible clean energy resources is key to the social and political acceptance necessary for the nation to proceed on a transformative low-carbon pathway.

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The future U.S. electric system anticipated in any of the deep-decarbonization scenarios will be even more complex than it is today. It will have a different and much larger set of components, including dispatchable and non-dispatchable and decentralized and central-station technologies, and many more devices and controls that affect power flows on the high and low voltage systems. It will have customer-usage profiles that differ considerably from those that have existed even in the recent past.

Given the scope of the challenges and the inherent uncertainties about any individual pathway, the literature suggests that it will be important in the near term to keep as many clean-energy pathways on the table as possible. Betting on a single technology, or a narrow suite of technologies, would lock in a constrained pathway with fewer contingency options in the event that the world changes in ways that are hard to foresee. Diversity is a common feature of decentralized and resilient ecosystems. The same is true of the nation's future energy system.

- What are your thoughts on achieving this goal not by 2050, but by 2030, the date targeted in the Green New Deal?

Response from Dr. Tierney:

As I said in my prior response, I think that it will be much easier to accomplish 'modest' GHG emissions reductions than it will be to reach the levels of emissions reductions (e.g., at least 80 percent reductions by 2050) that are consistent with limiting the worst impacts of climate change. So, I think that an accelerated timeframe for such reductions will be even harder—even as I agree with the aspiration to reduce emissions as quickly and as deeply as possible.

In my view, the original Green New Deal resolution—that is, the non-binding one introduced by Senator Markey, rather than the binding resolution introduced by Senator McConnell and voted upon in late March 2019—sets an aspirational goal for decarbonizing the American economy, among other things. In terms of its goals for GHG emission reductions, I view it as more a statement about the imperative of action than a specific legislative agenda. I like its narrative that pulls together ideas for actions in different sectors of the economy, for investment in clean infrastructure, for a just transition that should accompany changes in energy systems and the ways Americans use energy. But it does not include any specifics about policy instruments, and therefore does not lay out either a legislative or as-yet-actionable strategy for accomplishing its objectives. (I don't think its intention was to do so at this point.) As a consequence, I do not

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see it as revealing a clear pathway for making the very challenging transition to a zero-carbon electric system by 2030.

- While we have seen information on 80 percent by 2050, do you have any thoughts on why we have not seen any substantial reports mapping out exactly how the nation could reach 100 percent by 2030?

Response from Dr. Tierney:

Although many individual companies and sub-national governmental entities and other institutions in the U.S. have committed to near-term zero-carbon electricity supplies for their own use, I am not aware of any organization that has offered a strategy for full decarbonization of the American economy (or even of its electric system) by 2030. Perhaps this reflects awareness of the significant political, cost, financial, scientific/technical, technological, legal, regulatory, behavioral, systems, and other impediments that stand the way of accomplishing such dramatic transformation of the economy so fast.

Looking at the power sector alone, the amount of long-lived capital stock (e.g., fossil power plants, transmission equipment, and consumers' energy-using equipment that does not now use electricity) that would need to turn over and be replaced by a combination of zero-carbon technologies in a single decade is enormous. And the challenges of accomplishing a 100 percent decarbonization goal by 2030 in a reliable and affordable way are daunting, especially in a federal/state system where collective action toward that goal depends upon bipartisan legislative consensus in Washington and/or the states, outcomes of myriad legal contests, and disbursed decisions in regulatory proceedings that focus on discrete issues rather than omnibus solutions.

Question 6: Your written testimony includes a pair of charts that show, as you wrote, "nearly every state experienced a reduction in CO_2 emissions from in-state power plants from 2005 through 2016." One of the states that stands out in the minority of those charts is Washington State, which appears to have both increased power sector emissions over that period, and to have increased the percentage in its power sector CO_2 emissions as well. Please expound on what might be happening in Washington State, specifically, to cause its power sector to be increasing its CO_2 emissions over a time period when "nearly every state" is going the other direction.

Response from Dr. Tierney:

In the data presented to the SENR Committee to indicate the progress that has been made across the nation to reduce carbon emissions, there are at least two states—Washington and Oregon—that warrant further explanation, so I appreciate this

question. The electricity sector in each of these two states has had relatively low levels of carbon emissions for many years, in light of the abundant hydroelectric resources available to the electric utilities in these states. Due to the combination of a baseline of low power-sector carbon emissions and variability in the availability of hydropower from year to year, small absolute increases in carbon emissions (from, say, the operations of gas-fired generating facilities to make up for low-hydro years) can lead (mathematically) to higher percentage changes. Unlike in many other states on the chart I presented in my testimony and where there have been significant structural changes in the electricity supply portfolios, Washington (and Oregon) experienced small absolute (and somewhat anomalous) increases in 2016 relative to 2005, but the power sector in those states is still relatively clean.

Question 7: Clearly the power sector is not the only industry contending with emissions. What other sectors of the economy should Congress focus on to reduce overall emissions?

Response from Dr. Tierney:

As power-sector emissions have gone down in recent years, the relative importance of reducing emissions from the transportation sector, from buildings, and from industry has increased. The extensive literature on decarbonizing the American economy points to the importance role of electrifying certain activities and processes in these other sectors (e.g., through adoption of electric vehicles, through adoption of electrical technologies to heat and cool buildings, through changing industrial processes that now use fossil fuels), while continuing to reduce carbon emissions from the power sector as electrical demand grows. The literature suggests that by 2050, electricity generation could double relative to today's output. Without much deeper electrification and a lower-carbon electricity system, it will be much harder, technically, and much more expensive for the nation to deeply reduce its GHG emissions.

I hope that Congress looks for ways that existing or new federal policies could support development and application of cost-effective and innovative emissions reductions in buildings, industrial processes, and vehicles, fuels and transportation systems.

Questions from Ranking Member Joe Manchin III

Question 1: You pointed out in testimony that, although there was an increase in carbon emissions from 2017 to 2018, overall, power sector emissions declined substantially over the past decade, with electricity generation and use remaining relatively flat. Carbon dioxide declined by about 28 percent from 2005 through 2017.

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What technologies have you seen in practice that have shown the most success in emission reductions so far?

Response from Dr. Tierney:

In the power sector, the emissions reductions that have occurred over the past decade have resulted from a combination of technologies:

- Private companies' application of hydraulic fracturing and directional drilling to tap domestic natural gas resources at relatively high speed and low cost, leading to availability of abundant supplies of natural gas at relatively attractive prices;
- The existence of a large number of new gas-fired combined cycle power plants around the country that have been installed in the post-2000 period and which were underutilized until that low-priced gas became more widely available in the market. With low-cost fuel supply, these gas-fired combined cycle plants (as well as new combustion turbine generating units) could produce power more efficiently than many other, older fossil steam units (such as those that burned coal).
- Wind and solar technologies that experienced significant cost reductions and performance improvements over the past decade, so that (for example) wind turbines and projects could access areas (e.g., altitudes) with higher-quality wind, and solar projects could be installed relatively affordably on residential and commercial rooftops and in utility-scale solar systems.
- Energy efficient appliances (such as LED lighting) that enabled consumers to experience high-quality energy services with less need for electricity.
- Communications and control technologies that enable customers to better manage their electricity usage (and tune it up or down in ways that have afforded grid operators with flexible resources they need to operate the electric system reliably and efficiently).
- Battery-storage technology improvements, which have led to storage applications (along with gas-fired resources and demand-response technologies) that have begun to support the integration of many non-dispatchable wind and solar facilities on local distribution system and on the higher-voltage electric grid.
- Systems-integration, power-control and communications technologies that allow grid operators to better visualize and reliably control power flows on the system.
- The continued operation of existing nuclear plants, which currently provide three-fifths of all carbon-free electricity in the nation.
- High-voltage, direct-current transmission facilities that, under certain configurations and conditions, allow for larger quantities of power to move across regions and at lower cost than in conventional alternating-current technologies.

The successful deployment, retention and operations of these low-carbon technologies has been supported over the years through a wide variety of federal and state policies

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(including tax credits, appliance efficiency standards, regulatory policies and rules in wholesale power markets, R&D, among many others).

What technologies have you seen at DOE and the labs that have a great deal of promise for providing a reliable energy with a lower emissions profile?

Response from Dr. Tierney:

The technologies I describe above have benefitted from federal support for RD&D, with that work carried out by the national labs as well as in academic institutions. These efforts are supported by DOE energy-program offices, including ARPA-A.

What can Congress do to foster commercialization of these innovative power sources?

Response from Dr. Tierney:

Congress can continue to support various activities and approaches, including:

- Funding RD&D that addresses technical, cost and performance issues, including work on materials, systems-integration, system modeling, and advanced manufacturing that affect the understanding of and eventual development/availability of technologies that affect their commercial deployment.
- Authorizing agencies' (e.g., the Defense Department) interest in testing and deploying early stage technologies.
- Ensuring access to public lands (including offshore wind areas) for renewable development.
- Providing tax provisions (such as the new 45Q) that support private investment in advanced and/or clean-energy technologies.

Question 2: Between 1990 and 2014, total greenhouse gas emissions increased by 30 percent, but three quarters of those emissions came from three sectors – electricity, manufacturing, and transportation. As a large scale energy source, nuclear power has a significant potential to contribute to emissions reductions goals. In the U.S., due to phase-out policies and financial challenges, 30 gigawatts will be lost by 2025. This represents an 8.7 percent increase in carbon emissions for the U.S. power sector and according to an MIT study will cost the country $7 billion a year.

What potential do you see nuclear power having to aid in the reduction of carbon emissions in the future? What about utility scale nuclear versus small modular reactors (SMRs)?

Response from Dr. Tierney:

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I agree with the premise of the question, which points to the important role that nuclear energy plays in helping the nation meet its electricity requirements without producing GHG emissions. (In my response to a prior post-hearing question from Chairman Murkowski's post-hearing Question #1, I describe the economic, carbon-reduction and national-security value of retaining safely operating existing nuclear plants in the U.S.) The federal government has been a critical actor in supporting the development of commercial nuclear technology, and will—I hope—continue to do so regarding next-generation nuclear technologies, through a combination of R&D support, tax policy, environmental regulations, various technology and safety standards, and policies that underwrite technological development risk.

In this context, I think it is important for the U.S. federal government to continue to help support such things as R&D on materials and advanced reactor designs, advanced manufacturing systems, regulatory reforms to align federal safety reviews with the characteristics of advanced reactor designs, methods to mitigate the risks associated with early-stage demonstration projects, and so forth. Given the extremely challenging economic and investment conditions associated with the deployment of conventional reactors, I encourage continued federally supported work on small modular reactors which aim to use advanced materials, reactor designs, manufacturing models, and investment approaches on nuclear technologies with very different cost, operational, waste-management, and security profiles from the existing commercial reactor fleet.

Question 3: We have seen the European electricity sector transformed in the past decade. For example, last year the United Kingdom went coal-free for a record three days, relying on gas, renewables, and nuclear instead to keep the lights on. In fact, both UK Prime Minister May and German Chancellor Merkel announced plans to phase out coal in the next decade. European Union countries have committed to achieve 32 percent renewables by 2030, and an organization of 3,500 European electric utilities has committed to 100 percent carbon neutral power generation "well before" 2050. Aggressive climate policies are driving these decisions and European customers also seem willing to pay more for their electricity. Depending on the country, these shifts have occurred because of an emissions trading system or subsidies for wind and solar, and, in others, because of the ability to draw from significant hydropower or nuclear resources.

What are the differences between these European countries and the United States that make shutting down coal a feasible decision for them and more challenging for us? Can you speak to the implications, both positive and negative, of their plans to phase out coal?

Response from Dr. Tierney:

There are several reasons why many European countries have been moving faster than the U.S. to reduce if not eliminate their reliance on coal. For example:

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- There has been a deeper level of consensus among policy makers, corporations, and civil society in many large European countries (as compared to the U.S., until recently) that climate change is occurring and that carbon emissions from human activity are contributing to it. This has supported a greater degree of political will in many of those European countries to take action to reduce such emissions.

- The economic content in Europe is one in which energy (e.g., electricity, gasoline) prices have historically been higher than in the U.S., with significantly less energy used per capita than in the U.S. These differences in the energy intensity of national economies in Europe versus the U.S. has contributed to the varied political and economic reactions to changes in domestic energy systems.

- There is an energy system in the U.S. where states play a strong role in shaping trends in electric-sector policies, plans, and resource portfolios—and where significant regional variation exists across the American states with regard to political, regulatory and popular support for maintaining coal-fired generation (until the past decade or so).

- Notably in the U.S., the most significant driver of reduction in coal-fired generation is less national political will than the reality of market forces, combined with targeted state policies and federal support for technological innovation. For example, key factors affecting this outcome are:
  - The low price of natural gas, given development of the U.S.'s abundant supplies of unconventional natural gas which are now economically accessible through the application of hydraulic fracturing and directional drilling in the past decade.
  - Federal and state policies (such as federal appliance efficiency standards and federal energy management programs, and states' policies that advance the installation of efficiency measures by utilities and other service providers) that have helped to flatten electricity demand;
  - Federal policies that support R&D on renewable energy technologies and states' policies to promote the development and adoption of renewable energy; and
  - States' policies to reduce carbon emissions (e.g., through the Regional Greenhouse Gas Initiative) or maintain zero-carbon electricity sources (e.g., Illinois' and New York's zero-carbon emissions programs aimed at maintaining existing nuclear plants that are financially at risk of retirement).

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Questions from Senator Mazie K. Hirono

Questions: In your testimony, you stated that "greenhouse gas emission reductions are not happening fast or deeply enough." The Department of Energy's Energy Information Administration ((EIA) projects the U.S. power sector will only cut emissions 34 percent by 2050 compared to 2005 levels, meaning only an extra 6 percentage point cut below the 28 percent reduction achieved by 2018. That is not fast enough to make the economy-wide reductions needed to avoid the worst impacts of climate change. For many years, I have called for a national renewable power standard to set a clear target for power companies to meet while helping create American jobs in technology development, manufacturing, and installation. From your testimony, I understand you would prefer to include other low-carbon sources of power in any national policy. Do you think a national power standard would help drive down the costs of zero-carbon power sources and accelerate cuts to greenhouse gas emissions from the power sector (compared to the current policy projections offered by EIA)? If you think a national power standard to reduce GHG emissions is important, do you have any recommendation for design of such a standard?

Response from Dr. Tierney:

I agree with Senator Hirono that a national renewable power standard would help to drive down the costs of zero-carbon renewable power sources and accelerate cuts to GHG emissions. Moreover, a national clean-energy standard, with eligible resources including not only renewable power sources but also other zero-carbon-emitting resources, would have amplify those positive effects and, according to numerous studies (e.g., https://www.thirdway.org/report/clean-energy-standards-how-more-states-can-become-climate-leaders), would do so in a way that provides for reliable clean power at lower costs.

Regarding design elements of a clean-energy standard, I encourage the Senate to look at various studies and policy discussions that address an efficient and effective design for a clean energy standard. Over the past decade, many parties have examined how to structure CES policies, including, for example:

- Resources for the Future (https://www.rff.org/events/all-events/a-federal-clean-energy-standard-understanding-important-policy-elements/;
- World Resources Institute (https://www.wri.org/blog/2011/04/how-design-clean-energy-standard);
- Center for Climate and Energy Solutions (https://www.c2es.org/document/an-illustrative-framework-for-a-clean-energy-standard-for-the-power-sector/);
- Breakthrough Institute (https://thebreakthrough.org/articles/clean-energy-standards); and
- Brookings Institute (https://www.brookings.edu/wp-content/uploads/2016/07/05_clean_energy_aldy_paper.pdf).

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Questions from Chairman Lisa Murkowski

Question 1: Nuclear reactors provide clean, emissions-free power. As we look across the nation at the nuclear reactors slated for retirement before the end of their operating licenses, I am concerned about the long-term consequences.

- **I understand that the costs of maintaining a nuclear reactor on standby are unmanageable, so when these reactors close, they will not reopen. Do you agree with that assessment?**

Yes.

- **Are you concerned about the long-term consequences if our current nuclear fleet shrinks considerably?**

Yes. The US nuclear fleet is the largest in the world at over 100GW. Replacing that stable source of electricity will be a challenge.

- **If so, what are the ramifications?**

Replacing the lost nuclear capacity can be done with fossil generation sources, which in the current market means natural gas, or it can be done with renewable resources, which will require storage and or back-up generation assets given the intermittency of non-dispatchable renewable resources. Another option, of course, is increased end-use efficiency, but given the size of the nuclear fleet it is likely to be some combination of all of the above.

It is likely that replacing the existing nuclear fleet with other generation assets will lead to a higher price to consumers. This follows because too often the focus on electricity prices and competitiveness of different technologies is rendered to a discussion of levelized costs. When comparing different sources of generation this can be very misleading, particularly when comparing non-dispatchable resources to dispatchable resources. This point was raised by Paul Joskow in his AER article, "Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies" (citation: American Economic Review, 101(3): 238-41, May 2011).

A more relevant metric is the cost of a *stable* kWh of electricity. This requires one to pair the costs of non-dispatchable resources with (1) storage, which leads to an overnight cost that is comparable to nuclear, or (2) standby backup generation sources, which is unnecessarily redundant. Hence, a considerable reduction in the size of the nuclear fleet will require new capacity to be added, which could take many forms. This will likely result in an increase in the price of electricity to consumers, absent subsidization, as the significant upfront investments must be recouped.

Question 2: While concerned about premature closures in today's U.S. nuclear fleet, I am bullish on the future of advanced reactors. Last week, Dr. Birol of the International Energy Agency and I discussed the importance of re-establishing U.S. global leadership in nuclear to ensure that advanced reactors are designed and deployed here. During the hearing, the important government

support that brought wind and solar technologies to market and brought down the cost curve was discussed. I have been working on policies that will do the same for advanced nuclear technologies like small modular reactors. These advanced reactors may provide different value streams like high-temperature heat for manufacturing or off-grid power to remote communities like those in Alaska. They will also provide power to the grid. As you look forward to these next-generation technologies, what kind of value will advanced reactors provide and do you anticipate advanced reactors playing an important role in a lower-emissions economy?

Given overarching concerns about environmental attributes of power generation, it is utterly necessary that new technologies be developed and deployed. Nuclear energy is a technologically viable option. Cost concerns are very real, but small-scale, modular, advanced nuclear reactors could play a significant role in providing stable and reliable power and heat. Notably, this can be used in off-grid applications, but is also applicable for industrial and grid-connected applications, which would enhance the zero-emission capability of grid-connected generation. Modularity also allows gradual scale-up, which can possibly address concerns about a single, large, "bet the company" investment that most modern utility scale nuclear facilities today represents. Moreover, it can provide an avenue to cleaner local air and lower carbon emissions from the gen fleet of the future.

<u>Question 3</u>: You close your written testimony by noting that flexible, incentives-based policy is a more effective way to reduce emissions than a "top down" and prescriptive approach that mandates certain actions across all regions.

- **What are some examples of effective incentives that help reduce our emissions?**

I will focus on local air emissions because incentives that have encouraged the deployment of renewables have a questionable impact on the level of CO_2 emissions, with evidence that the largest CO_2 emission reductions have come from the retirement of old coal facilities. The retirement of old coal in the US is a product of the age of the coal fleet and the serendipitous abundance of natural gas supplies coupled with a relatively new fleet of natural gas combined cycle gen units domestically.

On local air emissions, measures that provides economic incentive in the addressment of pollutants such as SO_X and NO_X have been remarkably successful, so much so that acid rain concerns have been diminished and local air quality has improved in many locations across the US over the last 50 years. Much of this was a shift in air quality regulations that encouraged the adoption of available technologies at relatively low cost.

This raises an important point. Incentive-based policies and regulations can have much greater impact when they allow point-source emitters the flexibility to take different pathways. One such pathway might be technology adoption at existing facilities (such as scrubbing technology) or replacement of old facilities with newer ones. In either case, the end result is the same. Policies/regulations that allow this flexibility enable least cost outcomes with the desired result.

- **What are some of the risks of prescriptive mandates that do not recognize regional differences?**

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In general, top-down, overly prescriptive mandates remove flexibility from the set of choices that are available to reduce emissions. This may play well in some regions of the US while imposing burdensome costs in others, which can disenfranchise certain constituencies. In general, when constraints are added to any system costs increase, and the more binding the constraints are, the greater the cost increase. Hence, flexibility allows the system/market to avoid the most binding constraints thereby keeping costs from rising dramatically. This is a general answer, of course, and any specific proposal would need to be analyzed with this in mind.

Another point worth making in this context is that policies – subsidies – that target certain technologies can create an unlevel playing field that may hinder other, potentially equally effective technological advances. Moreover, once subsidies are enacted, they can be difficult to remove, which will inevitably lead to different subsidies when another technology solution is desired. Remarkably, there is a long and robust literature on the inefficiencies of subsidies in oil producing regions, where the subsidies to domestic consumers are part of the "social contract" between the government and the population. Subsidies lead to an over-deployment of capital and over-consumption in certain end-uses that create imbalances that must eventually be reconciled. This is a lesson that actually applies more broadly than just to oil-producing states. There are valid arguments for subsidies, such as addressing externalities, but too often the arguments are presented in a vacuum without acknowledging there may alternative pathways to a desired outcome. For instance, is subsidizing renewables superior to increasing energy efficiency, using billing incentives to alter consumer load patterns, or taxing the externality that is intended to be addressed? In some case, perhaps, but in others, perhaps not. It is precisely this point that argues against subsidies to any energy source, fossil or otherwise, and supporting flexibility in the energy system.

<u>Question 4</u>: In order to see increased adoption of carbon capture, we know we need to make some important breakthroughs in technology and cost.

- **What role will carbon capture play in our clean energy future?**

Potentially a very significant one. Globally, hydrocarbon fuels still account for the vast majority of delivered energy. Even as low carbon energy sources grow, the overall energy system is growing as developing economies advance. In developing Asia, this represent over 3.4 billion people. So, while the shares of some hydrocarbon fuels may decline, this does not translate into a reduction in their use. The core of this is "scale". The scale of the energy system is massive and growing, and hydrocarbons represent just over 80% of the system. Moreover, this fraction has not changed very much in the last 35 years. So, if CO2 emissions are to be reduced through simple displacement of hydrocarbons from the energy system, the scale of non-carbon fuel sources required for deployment is unprecedented. Not only must non-carbon energy sources capture all new demand growth, they must also displace existing hydrocarbons. Given the realities present in data, this is highly unlikely. For example, if hydrocarbons represent 80% of the global energy "pie", and the pie doubles in size, what share need hydrocarbons represent to still occupy the same absolute scale? The answer is 40%. Hence, carbon capture technologies will be vital to achieving a goal of reducing CO_2 emissions long term.

From 1985 to 2017, global primary energy demand has increase from 7,162 MTOE to 13,511 MTOE, according to the BP statistical review of world energy. This represents an 88.6% increase over 32 years.

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Over the same time frame, coal's share of global energy use fell from 28.7% to 27.6%, oil fell from 39.4% to 33.1% and natural gas rose from 19.5% to 23.4%. In sum, the hydrocarbon share of total energy fell from 87.7% to 84.1%. Note however, that the "size of the pie" almost doubled. In fact, the hydrocarbon share of total energy would have to fall from 87.7% in 1985 to 46.5% in 2017 for hydrocarbon demand to have just remained flat. As some argue, that plus more must happen by 2050, just over 30 years from now. Given demand growth in the developing world will overwhelm demands in the OECD by 2050, the majority of the displacement must come in the developing world. This is a tall task by any measure. Hence, carbon capture technologies stand to play a significant role in lowering CO2 emissions longer term, and technology-focused policy is critical to this end.

- **What are the things that Congress can do to accelerate the development of carbon capture technology?**

Aggressive and unprecedented support for energy technology development across the entire value chain. This is not limited to capturing emissions and injecting CO_2 into subsurface formations for permanent storage or to enhance oil recovery (sometimes captured in the CCUS umbrella). Support should also be available for *any* technology that mitigates CO_2 emissions, which can include efforts aimed at separating hydrogen from methane (CH_4 to $C + 2H_2$), using the hydrogen as a fuel source and the carbon as a feedstock for high value carbon-based products, and improving energy efficiency. Such technologies, if proven cost effective, will avoid potential concerns related to CO_2 injection and storage while creating an additional value proposition for removing carbon from the hydrocarbon fuel source (carbon feedstocks) and lowering the cost of energy services to consumers (efficiency). In any case, level support across all options is needed for the most effective option to ultimately be revealed and adopted, which may differ across regions.

<u>Question 5</u>: In your written testimony you state that energy storage technology has the potential to help transition to a cleaner grid because storage can regulate the delivery of power from intermittent renewable resources.

- **Are government and industry providing the needed investments to rapidly deploy more energy storage on the grid?**

The potential impact of energy storage is game-changing, and it has long been recognized as such. It only now is moving into the public discourse. But, the amount of storage that is required to balance load in a system dominated by intermittent resources is significantly higher than when added to a system with dispatchable resources. This point was elegantly made by Peter Hartley in his 2018 article in the *Energy Journal*, "The cost of displacing fossil fuels: Some evidence from Texas." So, if policy is to continue to support larger scale adoption of intermittent renewables, then the answer to the question is likely "no". But, this gets back to the issue of flexible policy design referred to above.

- **If not, what else needs to be done?**

R&D is still needed. An answer here requires a dive into battery chemistry (an area we are actively researching), but the current technology may be approaching its limits, which requires advanced research.

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Funds dedicated in this direction could result in long term advances that provide an environmental benefit, as well as economic benefits that can lower system costs for consumers.

Question 6: Clearly the power sector is not the only industry contending with emissions. What other sectors of the economy should Congress focus on to reduce overall emissions?

The power sector may be the easiest sector to address, but other sectors, particularly those with high GHG intensity could bear significant benefit relative to cost. Agriculture is one such sector where GHGs such as N_2O could be mitigated through the use of existing technologies, such as biochar. Notably, this can also have ancillary benefits for water quality, irrigation demands, and algal blooms in the Gulf of Mexico. Of course, the cost-benefit must be supportive, but research aimed at specific applications in agriculture could bear significant benefits.

Transportation may be the most difficult to address, unless alternative vehicle technologies, such as electric or hydrogen, become more mainstream. Heavy industrial activities should also be analyzed. The production of cement, for example, is very CO_2 intensive, so technologies that result in more resilient cement for roads and other infrastructures could reduce the amount of cement manufacture required for a given amount of construction, which would, in turn, lower emissions.

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Questions from Ranking Member Joe Manchin III

Question 1: Dr. Tierney pointed out in her testimony that, although there was an increase in carbon emissions from 2017 to 2018, overall, power sector emissions declined substantially over the past decade, with electricity generation and use remaining relatively flat. Carbon dioxide declined by about 28 percent from 2005 through 2017.

What technologies have you seen in practice that have shown the most success in emission reductions so far?

What technologies have you seen at DOE and the labs that have a great deal of promise for providing reliable energy with a lower emissions profile?

What can Congress do to foster commercialization of these innovative power sources?

The largest gains have come from the retirement of coal in the power sector. This has occurred primarily due to the age of the US coal generation fleet, the abundance of low-cost natural gas, and the relatively new natural gas combined-cycle generation fleet. At the core of this has been the improvements in combined-cycle technology that manifested in the new gas-fired generation capacity built from 2003 to 2006 and the widespread use of horizontal drilling and hydraulic fracturing in the onshore US upstream sector. These two things in particular combined to render natural gas a lower cost option than coal in generating electricity, thereby resulting in the reduction of coal use. However, as coal is retired in favor of natural gas, there are limits to the amount of emissions reductions that can be achieved. This argues in favor of substantial research into new technologies that will be required to advance emission reductions.

What will this next generation of technologies be? That is difficult to say. While much is made of wind and solar technologies plus battery storage – and there is significant potential here – the scale-up in deployment is staggering and grossly underappreciated. In other words, it will take time and significant capital deployment. Moreover, since the delivery of stable, on-demand electricity is at the core of consumer demands, these technologies must be deployed simultaneously. Thus, significant storage capacity is required concomitantly with expansion of wind and solar generation capacity.

One potentially very promising technology invokes the old phrase, "What's old is new again." Nuclear technology continues to advance, and smaller scale (modular) nuclear deployment could be very valuable in delivering reliable energy services at scale. Other (non-nuclear) technologies that DOE and other organizations have been investigating include supercritical CO2, the Allam cycle, CCUS, hydrogen, etc. The list is impressively long, and highlights the risk of picking winners rather than directing intensive R&D efforts. Indeed, it could be argued that a global leadership mantle is at stake, and could be grabbed by being at the forefront of research that unlocks an scalable, economically viable energy future that solves the global CO2 problem, one that is at a scale much larger than asset deployment in the US energy system can address on its own.

This raises an important point. While much is made in the public/political discourse that directly ties mitigation of carbon emissions to decarbonization, the two need not be linked. In fact, with robust carbon

capture, carbon emissions can be reduced without decarbonizing the generation fleet. Arguably, this must be realized for global addressment of CO2 emissions. CO2 is a problem of the global commons. Closing the remaining coal plants in the US, which is a focus of much political activism, will not do much to solve the global problem. The relatively young and expanding coal fleet in developing Asia more than offsets what closing the rest of the US coal fleet will do for global CO2 emissions. In fact, despite the widespread closures in the US over the last 10 years, global CO2 emissions have risen. Moreover, demand in developing Asia, home to over 3.4 billion people collectively, is continuing to rise at a scale that requires ALL energy sources – from hydrocarbons to renewables. Hence, we would all be better served if resources were funneled into R&D so that long-term, technically and economically viable solutions can be rendered.

Question 2: Between 1990 and 2014, total greenhouse gas emissions increased by 30 percent, but three quarters of those emissions came from three sectors – electricity, manufacturing, and transportation. As a large-scale energy source, nuclear power has a significant potential to contribute to emissions reductions goals. In the U.S., due to phase-out policies and financial challenges, 30 gigawatts will be lost by 2025. This represents an 8.7 percent increase in carbon emissions for the U.S. power sector and according to an MIT study will cost the country $7 billion a year.

What potential do you see nuclear power having to aid in the reduction of carbon emissions in the future?

What about utility scale nuclear versus small modular reactors (SMRs)?

Nuclear technology has tremendous potential to aid in the reducing carbon emissions (and local emissions). At some level, active discussion of the deployment of nuclear technologies has to garner more of the stage in the energy/environment discussion. It is the most energy-dense zero emission source of energy available.

Small scale nuclear reactors have potential to deliver the aforementioned energy-dense zero emission electricity and they can lower the upfront fixed cost of nuclear technology relative to the traditional, utility scale nuclear plant. A central issue with nuclear technology is cost. The current cost per kW is amongst the highest of all energy sources, which makes financing and cost-recovery a challenge. Hence, cost and rate-of-return must be addressed if scale-up of investment is to occur.

Question 3: We have seen the European electricity sector transformed in the past decade. For example, last year the United Kingdom went coal-free for a record three days, relying on gas, renewables, and nuclear instead to keep the lights on. In fact, both UK Prime Minister May and German Chancellor Merkel announced plans to phase out coal in the next decade. European Union countries have committed to achieve 32 percent renewables by 2030, and an organization of 3,500 European electric utilities has committed to 100 percent carbon neutral power generation "well before" 2050. Aggressive climate policies are driving these decisions and European customers also seem willing to pay more for their electricity. Depending on the country, these shifts have occurred

because of an emissions trading system or subsidies for wind and solar, and, in others, because of the ability to draw from significant hydropower or nuclear resources.

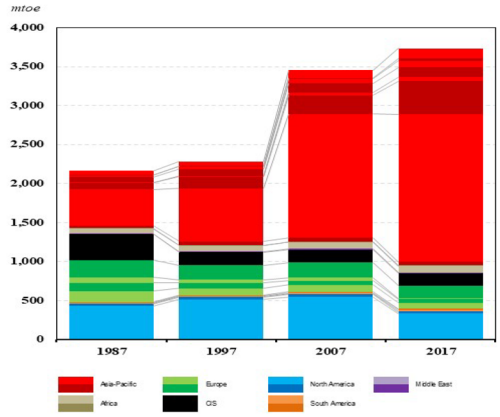
What are the differences between these European countries and the United States that make shutting down coal a feasible decision for them and more challenging for us?

Can you speak to the implications, both positive and negative, of their plans to phase out coal?

To begin, it is not possible to compare the experience in single European countries to that of the entire US. The fundamental issue is scale. It is more appropriate to compare all of Europe to the US, if a comparison is desired. The experience of one European country is better compared to individual US states, and when doing so it becomes evident that the ability to wheel power on a grid from other regions is critical to regional stability in power flows.

Phasing out coal should bring benefits of lower CO2 emissions and improvements in local air quality. Hence, the environmental benefits should be tangible at a local level. However, CO2 concerns are global. Globally, coal accounts for more that 35% of power generation and over 25% total energy use. European demand accounts for a relatively small fraction of this and the growth in developing Asia alone over the last 10 years exceeds the absolute level of demand in Europe (see figure). Moreover, Asian coal demand is set to continue expanding, meaning phase-outs in Europe are likely to have diminishing impacts. The challenge will come politically when any added cost outweighs the benefit.

Global Coal Demand (source: BP)



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Question from Senator Debbie Stabenow

Question: Hydrogen fuel cells, as I understand, have the potential to become a breakthrough source of zero-carbon electricity that can power our vehicles and provide backup power generation and energy storage. Could you please explain the role that hydrogen fuel cells can play in balancing electric loads on the grid, and whether we can leverage existing natural gas infrastructure to accelerate the adoption of this clean energy technology?

Indeed, this is a technology that deserves more attention. I recently co-authored (with Dolf Gielen (IRENA) and Morgan Bazilian (Colorado School of Mines)) a piece on this in Forbes that addresses this very question (see https://www.forbes.com/sites/thebakersinstitute/2019/02/01/re-envisioning-the-role-for-natural-gas-in-a-clean-energy-future/#547bb7c61fb0). The basic argument is summarized in that article's conclusion,

> "Creating hydrogen or synthetic methane from renewables is technically feasible, but is a relatively costly proposition. In contrast, hydrogen from natural gas, while economically feasible, faces technical and regulatory challenges that may limit its roll-out for small-scale use. But, application at scale is critical. For industrial energy needs, dispatchable power, and perhaps for transportation, hydrogen from natural gas with CCS may be a viable option in parts of the world. The realization of such pathways will allow a significant portion of today's energy infrastructure to play an important role in the evolution of global energy systems, which is critical to avoiding stranded costs and addressing the scale requirements of meeting future energy demands. This is especially important for many developing countries as they expand their natural gas infrastructure and contemplate future infrastructure investments.
>
> Longer term, cost reductions for electrolyzers and the continually falling cost of renewable electricity will enhance the economics of hydrogen from renewable sources in the coming decades. This has potential to create a virtuous cycle for renewables-based electrical grids as hydrogen can provide much needed flexibility to power systems, acting as a buffer to non-dispatchable renewable generation. Certainly, hydrogen is attracting increased attention as a viable energy option – car-maker Toyota has made a significant investment with the roll-out of the Mirai and its strategic direction. But, accounting for the full suite of environmental and system balancing benefits can further strengthen the case for hydrogen solutions in the future energy system."

Hydrogen is storable and can be done so locally, which provide an interesting avenue for back-up power generation for intermittent renewables. It also has potential to fuel modes of transportation, and it can utilize to some extent the existing fuel delivery infrastructure, which can lower deployment costs and mitigate stranded costs. Hydrogen can also be phased, first introduced as a fuel source from natural gas then as a fuels source derived from renewables. This can allow for a smoother transition of the energy system.

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Questions from Senator Angus S. King, Jr.

Questions: As we look toward greater electrification in the economy, particularly through the growth in electric vehicles, is the grid infrastructure of today equipped to handle that new demand? In terms of existing capacity, technology, and flexibility? If not, what are those infrastructure gaps and how can we best address them?

Long term, no. In the near term, we are likely ok with some regional exceptions. But, as we move forward, if EVs become more widely adopted, the current grid will need to be able to handle much more power flow overall and will need to be able to do so in more locations and with greater bi-directional frequency. This presents a challenge that utilities have long understood, and one that electricity rates (prices to consumers) must ultimately reflect. The gaps in the current system are best understood at a local level because they will not be the same everywhere due to differences in load, new technology uptake, and existing infrastructure. Hence, the solutions are best addressed at the local level. Utilities understand their service territories better than anyone. So, they are likely best suited to deal with shifting consumer demands. Hence, ensuring that utilities and other local service providers are equipped to do so will inevitably ensure reliability on an evolving grid.

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Questions from Senator John Hoeven

Question 1: You state in your testimony that absent investments in infrastructure and technology, new technology remains "on the bench." In North Dakota, we are promoting two projects, Project Tundra and the Allam Cycle, which are carbon capture retrofit projects aimed at reducing CO_2 emissions while continuing to supply baseload power to the grid. Will you elaborate on the investment needed in both the private and public sectors to make these technologies economically feasible?

Transmission infrastructure is critical for scale and integration of new projects such as those mentioned to be achieved. As new technologies are integrated, grid expansion can benefit their profitability. As one example, consider the case of ERCOT (Texas) where the $7 billion CREZ expansion helped facilitate better integration of the massive wind resources in West Texas. Absent that infrastructure investment, those resources would have been underserving of Texas load and profitability compromised. As another example, in Northwest Europe there is active interest in expanding transmission infrastructure to better integrate Norwegian hydro capacity with Danish wind. The two resources can complement each other to provide stable, zero emission electricity. Farther south in Germany, an inability to expand transmission from northern to southern Germany has inhibited deeper penetration of renewable resources, and played a role in coal generation in Germany even as nuclear is phased out. Hence, when one thinks of generation assets, it is important to not disentangle their deployment from transmission. They are all needed to provide reliable supply to load that varies throughout each day. This latter point is a major reason the modern grid was developed, so utilities could reliably supply their customers even in the event of a local unplanned power plant outage. This raises an old but oft underappreciated tenet of energy security – the capacity/ability to trade is great facilitator of reliable access to supply.

With regard to the projects in North Dakota, adequate capacity to connect to other regions can help facilitate expansion of proven technologies thereby allowing the realization of significant scale economies and hence lower costs.

Question 2: One of North Dakota's major utilities, Basin Electric Power Cooperative, through its for-profit subsidiary, Great Plains Synfuels Plant, owns and operates the only commercial-scale coal gasification plant in the United States that manufactures natural gas. The Synfuels Plant supplies CO_2 to the world's largest carbon capture and storage project in the world. Dakota Gas currently captures between 2.5 and 3 million metric tons of carbon dioxide per year and utilizes it for enhanced oil recovery. What regulatory policies does Congress need to review to ensure more technologically advanced projects, such as this one employed by Great Plains, are successful?

45Q effectively places a price on CO2 that allows for cost recovery through the tax code. Hence, a review of the "price" that is assigned in 45Q is worthwhile, particularly if a specific goal of carbon capture is targeted. In other words, if the marginal social cost of CO2 (the cost of the externality) is assessed to be $35/tonne, then 45Q should reflect that cost.

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Of course, more direct methods could also be deployed to drive the internalization of the cost of CO2 emissions, for example through direct taxation. In general, disincentives (tax) could be deployed to achieve a goal that ultimately pays for itself. For example, a CO2 tax could be avoided through tax write-offs for R&D into anything that reduces CO2 release to the atmosphere, including sequestration. This would encourage private sector R&D that could lead to a technology that would ultimately allow the innovator to avoid the tax altogether when the technology is deployed, not to mention profit from its commercialization. So, such an approach would provide both short and long term incentives to firms to invest in R&D.

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Questions for the Record Submitted to Ms. Lisa Jacobson

Questions from Chairman Lisa Murkowski

Question 1: Nuclear reactors provide clean, emissions-free power. As we look across the nation at the nuclear reactors slated for retirement before the end of their operating licenses, I am concerned about the long-term consequences.

- I understand that the costs of maintaining a nuclear reactor on standby are unmanageable, so when these reactors close, they will not reopen. Do you agree with that assessment?

  ANSWER: Thank you for the question. This is not an area of expertise for BCSE or me personally. However, more broadly, enacting market-based policy frameworks that recognize the environmental attributes of all generation sources is critical to address climate change and reduce greenhouse gas emissions. Nuclear energy should be eligible, just as all other sources of electricity, in such a framework.

- Are you concerned about the long-term consequences if our current nuclear fleet shrinks considerably?

  ANSWER: Nuclear energy now provides approximately 20 percent of U.S. electricity generation. Similar to above, policies should be fuel neutral and focus on the outcomes that the nation seeks. This includes environmental, economic and national security factors. BCSE does not have a public position on this question.

- If so, what are the ramifications?

Question 2: While concerned about premature closures in today's U.S. nuclear fleet, I am bullish on the future of advanced reactors. Last week, Dr. Birol of the International Energy Agency and I discussed the importance of re-establishing U.S. global leadership in nuclear to ensure that advanced reactors are designed and deployed here. During the hearing, the important government support that brought wind and solar technologies to market and brought down the cost curve was discussed. I have been working on policies that will do the same for advanced nuclear technologies like small modular reactors. These advanced reactors may provide different value streams like high-temperature heat for manufacturing or off-grid power to remote communities like those in Alaska. They will also provide power to the grid. As you look forward to these next-generation technologies, what kind of value will advanced reactors provide and do you anticipate advanced reactors playing an important role in a lower-emissions economy?

ANSWER: This is an area for consideration as part of a broad research, development and deployment program for the U.S. Beyond, RD&D, BCSE recommends fuel neutral policies that would allow the flexibility, emissions and other energy resource benefits to be considered. Should Congress decide to develop such policies, they should be consistent with the project and investment cycles of a wide range of energy resources and projects.

Question 3: In order to see increased adoption of carbon capture, we know we need to make some important breakthroughs in technology and cost.

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- What role will carbon capture play in our clean energy future?

  ANSWER: Carbon capture storage and utilization has the opportunity to play a role in reducing emissions is the fossil generation fleet and RD&D and well and incentives such as the 45Q tax credit can be helpful.

- What are the things that Congress can do to accelerate the development of carbon capture technology?

  ANSWER: Congress should consider extending and expanding the 45Q credit and maintaining a strong RD&D program. Critical to these efforts is close alignment with the private sector to be sure that the policies and RD&D efforts are addressing the most relevant and impactful challenges with cost reduction and uptake.

Question 4: Your written testimony notes that retailers, major technology firms, and a major oil company contracted for a record volume of 8.6 gigawatts of renewable power capacity in 2018. You also highlight pledges from other companies to double energy production or "green their vehicle fleets" with electric, fuel cell and renewable natural gas powered vehicles.

- What companies are leading the way and why have they undertaken these efforts?

  ANSWER: Companies through out the economy are taking on significant renewable energy and energy efficiency commitments. BloombergNEF released a report on this topic in January 2019[1] that is an excellent resource. It can provide more detail on the companies and market dynamics. Based on the discussions BCSE has had with its members and industry partners, this trend is increasing as companies seek to lock in low electricity prices, over a 10 to 20 year period, as the levelized cost of renewable energy technologies like wind and solar decline.

- Are these companies meeting their "green fleet" commitments?

  ANSWER: Please see the Climate Group as a reference for the green fleet efforts and progress towards meeting the targets.[2]

Question 5: Clearly the power sector is not the only industry contending with emissions. What other sectors of the economy should Congress focus on to reduce overall emissions?

ANSWER: Looking at US emissions data, all sectors of the U.S. economy need to further reduce emissions if the science-based targets are to be met. Please see a chart from the 2019 Sustainable Energy in America Factbook that shows that transportation, buildings, industrial and commercial sectors are

[1] https://about.bnef.com/blog/corporate-clean-energy-buying-surged-new-record-2018/
[2] https://www.theclimategroup.org/project/zev-challenge

making contributions and need to decarbonizes. Transportation is the largest emitter of U.S. greenhouse gas emissions currently.

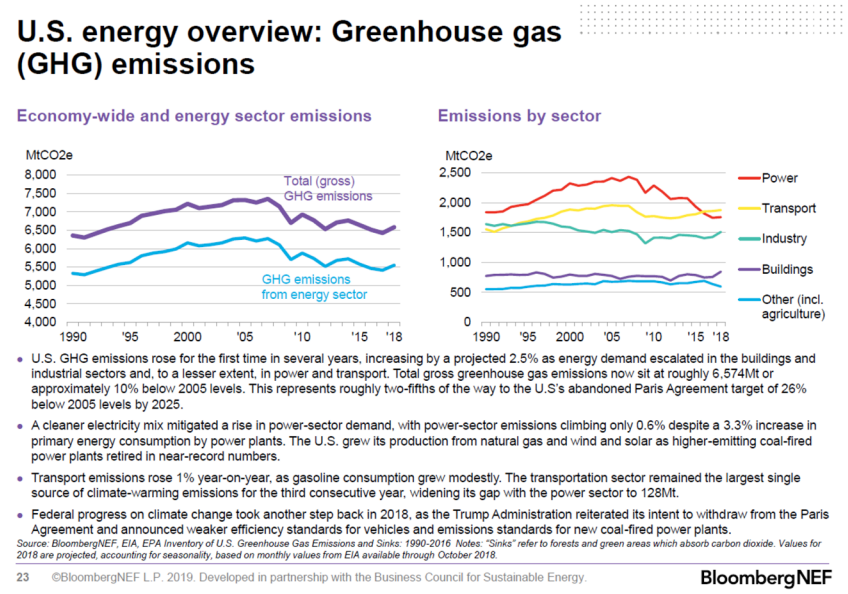

Chart Citation: www.bcse.org/factbook

Questions from Ranking Member Joe Manchin III

Question 1: Dr. Tierney pointed out in her testimony that, although there was an increase in carbon emissions from 2017 to 2018, overall, power sector emissions declined substantially over the past decade, with electricity generation and use remaining relatively flat. Carbon dioxide declined by about 28 percent from 2005 through 2017.

What technologies have you seen in practice that have shown the most success in emission reductions so far?

U.S. Senate Committee on Energy and Natural Resources
March 5, 2019 Hearing: *The Electricity Sector in a Changing Climate*
Questions for the Record Submitted to Ms. Lisa Jacobson

ANSWER: U.S. power sector emissions have declined significantly in the past ten years due a portfolio of power generation technologies and investment in energy efficiency. Specifically, energy generation technologies that have had an impact are natural gas and the broad portfolio of renewable energy technologies (biomass, waste to energy, biogas, hydropower, geothermal, solar and wind). Energy efficiency investments have lowered demand as well.

What technologies have you seen at DOE and the labs that have a great deal of promise for providing reliable energy with a lower emissions profile?

ANSWER: BCSE appreciates the broad scope of research, development and deployment initiatives at the Department of Energy and its members are most involved in the offices of Electricity, Fossil Energy and Energy Efficiency and Renewable Energy. Please see a link to the recent FY 2020 appropriations testimony BCSE submitted that shares more specifics on BCSE member views.[3]

What can Congress do to foster commercialization of these innovative power sources?

ANSWER: It is important to maintain a robust RD&D program at the Department of Energy and to ensure that it is including applied research. DOE and the labs should consult often with the private sector to ensure that the RD&D efforts are value-added and respond to the RD&D needs of the marketplace.

Question 2: Asian countries have rapidly expanded their use of fossil fuels in the past several decades and will continue to provide great market opportunities for exporting U.S. energy commodities. As we see in India, however, the rapid growth of coal consumption has occurred without the use of scrubbers, let alone carbon capture. It has led to dangerous levels of air pollution which have led to premature deaths. Therefore, the need for exporting U.S. clean energy technologies is ever present – both for air pollutants like SOX, NOX and mercury as well as greenhouse gas emissions. In our conversations with the International Energy Agency, it was noticeable that data remains somewhat unreliable in terms of how many coal plants are scrubbed in China and India but it is very apparent that they are not at the level we are with respect to controlling air pollution for point sources.

What technologies in the U.S. electric sector do you see as most important to export to other nations?

ANSWER: T he US is a technology leader in many areas and as the US approaches energy technology exchange and export strategies, it should consider the full suite of energy technologies. This is includes energy efficiency, renewable energy, natural gas and CCS as well as CCUS.

Jim Wood of the West Virginia University testified earlier this year that we remain unprepared to lead in this space – particularly on carbon capture. That is something that must be addressed. Whether you are

[3] Please see:
https://www.bcse.org/images/2019%20FPC/FY%202020%20Appropriations/BCSE%20Senate%20Letter%20re%20FY%202020%20EW%20Appropriations.pdf

talking about fossil technology or renewable technology, what is our current capacity to lead in this space?

ANSWER: BCSE is not an expert on the CCS or CCUS market, but believes that advancements in this arena are critical for global air quality and climate change mitigation reasons. U.S. technology, such as oxy-fuel combustion, as well as other technologies should be supported in the U.S. This investment and project implementation will assist with market leadership in other countries.

Question 3: Based on your testimony, in 2018 U.S. greenhouse gas emissions rose for the first time in several years, the U.S. economy grew at its fastest pace in 5 years, and the pace of our energy consumption outpaced the growth of our GDP. We can all agree that a healthy economy is great news but I think we can also agree that we don't want to be sliding backwards on our energy productivity. For decades we've been increasingly decoupling economic growth from energy consumption, meaning that our economy is becoming more and more efficient. Having an energy efficient economy means savings for businesses and consumers. It also makes the U.S. more globally competitive and attracts investment. I understand from your testimony that the reduction in energy productivity in 2018 is partially due to record hot and record cold days and increases in both air conditioning and heating needs.

The climate models tell us some regions of the country can expect more extreme hot and cold - do we expect climate change to further reduce our energy productivity?

ANSWER: If the U.S. accelerates investment in energy efficiency, natural gas and renewable energy as well as systems applications to optimize U.S. energy use, the nation will be better able to increase its energy productivity and reduce emissions. The 2018 data was noteworthy, but one year of data does not change the longer-term trend.

What can we do to resume the trend of increasing the energy efficiency of our economy?

ANSWER: Policies and incentives that align with the private sector and leverage private investment are the best ways to ensure that the U.S. maintains improvement in energy efficiency.

Question from Senator Debbie Stabenow

Question: Michigan leads the Midwest and ranks fifth nationally in clean energy jobs. Nevertheless, clean energy companies across Michigan say they face workforce shortages. In 2017, nearly 60 percent of clean energy Michigan businesses reported that it was "very difficult" to hire qualified workers.

I recently met with Donele Wilkins, founder and CEO of the Green Door Initiative, which aims to close this skills gap through workforce development programs that prepare Michigan workers with the certifications and training needed for green economy jobs.

How can Congress or state governments promote workforce development initiatives, like the Green Door Initiative, and connect jobseekers to clean energy industries?

U.S. Senate Committee on Energy and Natural Resources
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ANSWER: This is an extremely important issue. BCSE hears routinely of the need for recruitment into the energy sector. Congress might be able to assist with establishing a coordinated inter-agency effort to increase the profile and better align the resources that the federal government provides for energy sector workforce issues. These efforts should work in partnership with states and the private sector to leverage the efforts already underway.

Questions from Senator John Hoeven

Question 1: You mention in your testimony that carbon capture, utilization and storage (CCUS) can play a role in future energy generation. You also speak to new policies to help achieve these goals, such as the extended and expanded 45Q tax credit. What needs to be done to ensure that the 45Q tax credit for carbon capture and storage is available to be used more broadly by CCUS project developers?

ANSWER: The 45Q tax credit is a significant development as it has the potential to expand funding by improving the economics of CCS and CCUS projects. Key to realizing the potential is the development and release of implementation guidance by the IRS. Without the guidance, project developers are unable to determine the value of the credit and this is stalling investment.

With the delay in releasing the IRS guidance, extending the begin construction and credit expiration are being considered.

Further, for carbon utilization outside the realm of CO2-enhanced oil recovery, the 25,000 metric ton threshold is thought to be set too high. As carbon utilization efforts in fuels and building materials are in the early stages, Congress should consider action to lower the threshold level.

Thank you for the leadership you are providing on these important issues and we hope they are resolved quickly.

Question 2: It is my understanding that the credit cannot be effectively used in North Dakota because the regulations governing the definition of secure geologic storage are not available. I am working to reintroduce legislation that will solve the problem. What can be done to solve the problem so that new CCUS projects can be financed and constructed with the help of the Section 45Q tax credit?

ANSWER: Thank you Senator Hoeven for bringing this issue to the attention of BCSE. BCSE does not have a position on the legislation you mention, but would be pleased to meet with you and your staff to discuss it.

From: Richard Fennelly
To: fortherecord (Energy)
Subject: Electricity: Our Weapon to Reduce Unneeded Emissions (for Next Week"s Hearing)
Date: Friday, March 01, 2019 1:45:51 PM
Attachments: Optimization-Monitoring-Maintenance-of-Cooling-Technology-v2-subhead....pdf
COILPOD Energy Savings Data.docx

The cleaning and maintenance of HVACR cooling equipment, which is often skipped (particularly for refrigeration) can drastically cut unneeded power plant emissions.

The attached Kigali Cooling knowledge brief estimates global emissions reduction potential at 500,000,000 metric tons CO2eq yearly in Figure 1 on page 2. Also see Reference 7 on page 4 and the comments in the last paragraph on the left side of page 3. We estimate that the running of the current stock of poorly maintained HVACR cooling units and systems contributes ~7.2% to global CO2 emissions. With better cleaning and servicing that contribution could potentially be cut to ~5.8%, which is significant.

We think legislation is needed to force foodservice and healthcare owners to do several cleanings per year. Most are,not doing so. These regulations are akin to existing auto emissions inspection requirements that aim to cut a differing type of pollution.

I'm available on very short notice to discuss this topic which is even off the radar screen of the experts.

Regards
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Optimization, monitoring, and maintenance of cooling technology

KIGALI
COOLING EFFICIENCY PROGRAM

This Knowledge Brief from the Kigali Cooling Efficiency Program, outlines the need for maintaining and servicing of cooling technology. It estimates that better optimization, monitoring, and maintenance of cooling equipment the potential to save 30Gt of CO_2 emissions by 2050.

THE NEED FOR COOLING EFFICIENCY

Cooling is essential to health, prosperity, and the environment, underpinning many of the Sustainable Development Goals. Yet currently most cooling is energy intensive and highly polluting. Demand for cooling is booming, so there is an urgent need to not only cut pollution from existing cooling but to ensure future cooling needs are met sustainably.

COOLING ACCOUNTS FOR > 7% GHG EMISSIONS

Use of cooling technologies causes substantial global GHG emissions of between 3.8[1,2], and 4.1[3] $GtCO_2eq$ p.a. (>7% global emissions). The International Institute of Refrigeration has estimated that cooling consumes 17.2%[4] of global electricity (c.3,500 TWh p.a. based on 2015 consumption)[5]. Indirect emissions from electricity to power cooling technologies causes 63% of cooling emissions[6]. The impact of global GHG emissions from cooling equipment is projected to grow between now and 2050 as developing nations gain access to energy and new technologies. It is estimated that improving the efficiency of cooling equipment between now and 2050 can avoid the emission of approximately 80Gt CO_2eq.

OPTIMIZATION, MONITORING, & MAINTENANCE CAN REDUCE TOTAL COOLING GHG EMISSIONS BY 13%

Neglecting the optimization, monitoring, and maintenance of cooling equipment results in increased energy use, lower cooling performance, and shortens equipment life. Effective optimization, monitoring, and maintenance of cooling equipment could deliver substantial electricity savings of up to 20%[7] (700 TWh), particularly if equipment has not been maintained for a long time, leading to emissions savings of up to 0.5Gt CO_2eq p.a.

The global stock of room air conditioners is expected to grow from 900 in million in 2015 to 2.5 billion units in 2050. (Clean Energy Ministerial, 2016)

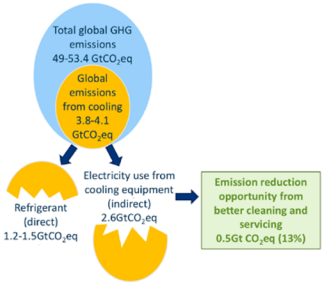
The Carbon Trust, the International Institute of Refrigeration, ans ASHRAE have supported the Kigali Cooling Efficnency Program in the publication of this brief.

'Better optimization, monitoring, and maintenance of cooling equipment has the potential to save 30Gt of CO_2 emissions by 2050 - contributing a further 38% of savings on top of those delivered through the planned phase down of high GWP refrigerants agreed at Kigali.'

– Didier Coulomb, Director-General, International Institute of Refrigeration

Policy makers should make effective optimization, monitoring, and maintenance of cooling equipment a key goal as the 20% savings in electricity translate into a 13% reduction in total cooling emissions (including GHG emissions from refrigerants). Figure 1 breaks down annual global GHG emissions to the opportunity presented through better optimization, monitoring, and maintenance of cooling equipment.

Figure 1 – Breakdown of annual total global GHG emissions to the cleaning and servicing opportunity



Sources: PBL Netherlands Environmental Assessment Agency, 2017; International Institute of Refrigeration, 2017; IPCC, 2014; Green Cooling Initiative, 2016, Carbon Trust analysis. All carbon savings numbers in Figure 1 relate to potential cumulative savings from now to 2050. They represent an initial, indicative view of savings and will be refined through further work.

SECTOR FOCUS: UNITARY AIR CONDITIONING

Unitary air conditioning (UAC) refers to ductless split, ducted split and rooftop ACs, variable refrigerant flow (VRF) systems and self-contained units. Typically, one unit will be installed per room, apart from VRF systems and multi-splits which can be used to cool several rooms (Green Cooling Initiative, n.d.).

UAC is the largest cooling market with an estimated installed base of 870-950 million units (2017)[8], about 30% of the three billion pieces of cooling equipment in use around the globe (International Institute of Refrigeration). UAC annual sales were approximately 100 million units (2012) worth USD 73 billion (Green Cooling Initiative, n.d.).

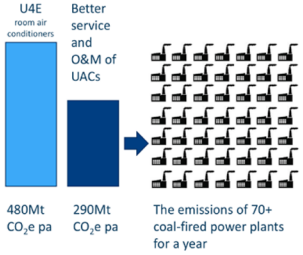
UAC ACCOUNTS FOR 30% OF ALL COOLING GHG EMISSIONS

Given their abundance, UACs are a major contributor to cooling related GHG emissions, estimated by the Green Cooling Initiative to be 1.28Gt of CO_2eq (in 2016) - equivalent to around 30% of total cooling GHG emissions in 2017. The 1.28Gt of CO_2eq break down into 330Mt related to refrigerant emissions and 950Mt from indirect emissions due to electricity consumption. Potential emissions reductions through effective optimization, monitoring, and maintenance are estimated to be 190Mt CO_2eq p.a. based on 2016 electricity consumption, rising to 290Mt CO_2eq p.a. by 2030[9] - equivalent to the emissions of over 70 coal-fired power plants in one year[10]. By comparison, the UN's United for Efficiency (U4E) estimates the total emissions savings opportunity across 150 developing countries of switching to energy efficient and climate friendly air conditioners at 480 Mt CO_2eq p.a. by 2030. Emissions reductions do not include those that exist due to better leakage management.

ACTION TO OPTIMISE, MONITOR AND MAINTAIN COOLING EQUIPMENT COULD SAVE 30GT CO_2EQ BY 2050

Following this same approach, an estimate for the potential impact of better optimization, monitoring, and maintenance on the overall cooling market to 2050 can be obtained. Based on total cooling emissions from electricity in 2016 of 2.6Gt CO2eq, 20% savings would deliver 0.5Gt CO2eq of savings p.a. Again assuming a 3% compound annual growth rate, total savings could reach 1.4Gt p.a. by 2050 - equivalent to the emissions of nearly 350 coal-fired power plants for a year. This would represent a cumulative saving of 30Gt by 2050.

Figure 2 – Potential emissions savings opportunities by 2030



COLLECTIVE ACTION IS ALREADY IMPROVING THE QUALITY OF UAC EQUIPMENT.

Given the scale of GHG impacts due to UAC, current global and regional initiatives are focused on controlling emissions due to product design inefficiencies, including the United for Efficiency initiatives, SEAD, CLASP, and EU EcoDesign.

THE IMPACT OF THESE INITIATIVES COULD BE LOST THROUGH POOR OPTIMIZATION, MONITORING, & MAINTENANCE OF COOLING PRODUCTS.

In addition to initiatives encouraging use of energy efficient products, policy makers are encouraged to develop national cooling equipment optimization, monitoring, and maintenance competencies in industry and the user base. This could include:

- Setting up an independent national standards body
- Creation of national standards for cooling optimization, monitoring, & maintenance.
- Programme of audits of refrigeration technologies to identify optimization, monitoring, & maintenance opportunities
- Investment in facilities providing best practice training in, as examples, equipment optimization and monitoring, supplier maintenance, or customer maintenance management programmes
- Developing supply chains for optimization, monitoring, & maintenance technologies.

Adoption of such practices could reduce needless emissions due to poor optimization, monitoring, and maintenance practices.

OPTIMIZATION, MONITORING, & MAINTENANCE PROJECTS

From initial research undertaken as part of preparing this brief, few examples of programs focused on better optimization, monitoring, and maintenance of cooling equipment have been uncovered - possibly reflecting difficulties implementing programs in some hard-to-reach sectors (e.g. residential) or that these elements in other sectors (e.g. commercial) are not made explicit. Nevertheless it seems likely that optimization, monitoring, and maintenance programs represent a major opportunity for energy and emissions savings. The following examples of what has been done give a sense of what can be implemented on the ground to take advantage of this huge opportunity.

ASHRAE

A trial to understand the benefits of coil cleaning was conducted at 1500 Broadway, Times Square in New York City between July and September 2005. The 34 storey building has 4 air handling units servicing 111 500 m^2 of air conditioned and heated space. The trial showed that good maintenance and operating practices including coil cleaning significantly improved the energy efficiency of the HVAC&R systems by 10% to 15% and delivered comfort increases. The trial also identified other optimization and maintenance processes that will improve energy efficiency for years to come. ASHRAE (2006)[11].

DEFRA UK

As part of a UK Department of Food and Rural Affairs Programme identifying reductions in energy inputs to the food industry, a trial was undertaken to assess the impact of applying low cost maintenance measures to commercial fridges at the University of Bristol Langfood Canteen. The canteen provides 200 to 300 meals per day. One large upright fridge consumed 40% of the canteens cooling load. Inspection of the fridge showed it had a dirty condenser which when cleaned delivered an 8% energy efficiency saving. The fridge was also found to have too low a temperature set point which was raised from -21ºC to -16ºC, giving an additional 11% energy efficiency saving. Together these two measures delivered a 19% energy reduction. (Defra)[12].

THE CARBON TRUST

The Carbon Trust, the UK Institute of Refrigeration and the British Retail Association worked together to propose a set of monitoring, maintenance and technology optimization measures that when applied could significantly reduce emissions from retail refrigeration equipment. A basket of monitoring, optimisation and maintenance measures could improve energy efficiency by 20 to 30% (e.g. training, cleaning and maintenance, re-commissioning, set-point temperature, store temperature). Additional technologies could significantly increase these savings[13].

ABOUT K-CEP

The Kigali Cooling Efficiency Program (K-CEP) is a philanthropic collaboration launched in 2017 to support the Kigali Amendment of the Montreal Protocol and the transition to energy efficient, climate-friendly, affordable cooling solutions for all. K-CEP's secretariat, the Efficiency Cooling Office, is located at the ClimateWorks Foundation.

K-CEP SUPPORT FOR OPTIMIZATION, MONITORING, & MAINTENANCE

Optimization, monitoring, and maintenance represent a major opportunity for the range of projects and activities funded by K-CEP. Existing and future projects should consider the possibility of adapting or expanding their brief to include an optimization, monitoring, and maintenance element.

FEEDBACK ON THIS BRIEF

The Carbon Trust put together this brief for K-CEP with assistance from the International Institute of Refrigeration and ASHRAE. We would welcome any feedback on calculating the emissions reduction potential of better optimization, monitoring, and maintenance and on better understanding the landscape of optimization, monitoring, and maintenance more generally. Please contact Paul Huggins at paul.huggins@carbontrust.com.

CONTACT US

For more details please visit www.k-cep.org, follow us at @Kigali_Cooling, or contact us at info@k-cep.org.

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4. Cited in International Institute of Refrigeration, 29th Informatory Note: The Role of Refrigeration in the Global Economy, November 2015.
5. Based on 1737 Mtoe (= 20,201 TWh) of total electricity consumed globally in 2015. Taken from IEA, Key world energy statistics 2017, 2017, p41.
6. International Institute of Refrigeration, 35th Informatory Note, The impact of the refrigeration sector on climate change, December 2017
7. Research for this brief indicated savings could range from as low as 3 to 4% to as high as 60% or more. Multiple studies gave savings in the range 15 - 25%.
8. These estimates are based on 750 million UAC units in 2012 (Green Cooling Initiative) and 900 million UAC units in 2015 (Clean Energy Ministerial), extrapolated using a 3% compound annual growth rate (itself sourced from the Clean Energy Ministerial assumption that UAC units would reach 2.5 billion by 2050).
9. This assumes that the 2016 emissions of 1.28Gt of CO2e are produced by 843 million units, which rise to 1,268 units by 2030 and consume electricity with a constant emissions factor. The unit numbers are based on 750 million UAC units in 2012 (Green Cooling Initiative) and a 3% compound annual growth rate 2015-2050 provided by the Clean Energy Ministerial in 2016.
10. Based on calculations using the U.S. Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator.
11. Study Verifies Coil Cleaning Savings Energy. Ross D. Montgomery, P.E., Member ASHRAE; and Robert Baker, Member ASHRAE, ASHRAE Journal. Nov 2006. 34-36.
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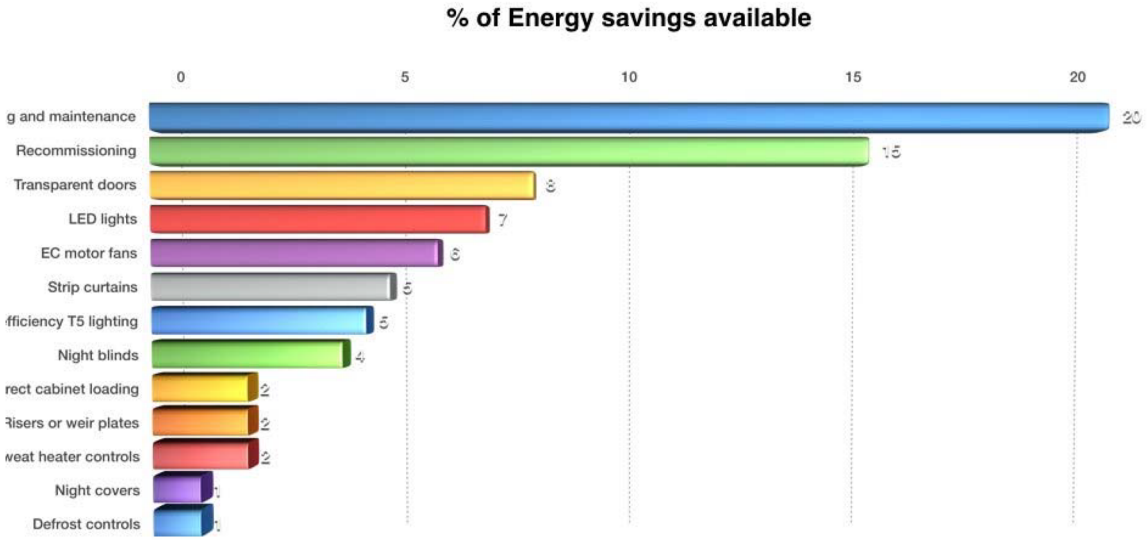
The Carbon Trust has identified cleaning and maintenance as the largest area for energy savings in cold chain refrigeration

"In the UK, refrigerated display cabinets use around 5,800 GWh/year. This is over a third of all the electricity used for refrigeration in the food chain and costs around £500m per year."

Refrigerated display cases rank number 1 in areas where energy use can be significantly cut. (source; Carbon Trust)



CONDENSER COIL CLEANING: ACTUAL DATA

The data presented below was generated by the Food Service Technology Center (San Ramon, CA) and announced at the RFMA (Restaurant Facility Managers Association) and CFESA (Commercial Food Equipment Service Association) 2015 annual conventions. The electric rate was at $0.11/KwH:

Double Door Merchandiser (6 years old):

Dirty: $1325/year/unit

Clean: $700/year/unit

Savings: 47% = $625/year/unit

Larger Double Door Fridge:

Dirty: 24 kwh/day/unit = $950 /year/unit

Clean: 13 kwh/day/unit = $517/year/unit

Savings: 46% = $433/year/unit

Single Door Freezer:

Dirty: $546/year/unit

Clean: $289 /year/unit

Savings: 47% = $257/year/unit

Double Glass Door Fridge:

Dirty: $439/year/unit

Clean: $219/year/unit

Savings: 50% = $220/year/unit

Additionally, the following three data points were announced at the 2015 RFMA meeting from three restaurants: (1) Glass door merchandiser: $300/year savings; (2) Glass door merchandiser: $600/year savings; and (3) Solid door refrigerator: $590/year savings.

The average of all seven data points reported herein: $432/year savings

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