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S. HRG. 116–296

AN EXAMINATION OF THE DEPARTMENT OF ENERGY'S CARBON CAPTURE, UTILIZATION, AND STORAGE PROGRAMS AND TESTIMONY ON S. 1201, THE ENHANCING FOSSIL FUEL ENERGY CARBON TECHNOLOGY ACT OF 2019

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED SIXTEENTH CONGRESS

FIRST SESSION

MAY 16, 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

37–308 WASHINGTON : 2020

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THURSDAY, MAY 16, 2019

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

The Committee met, pursuant to notice, at 10:01 a.m. in Room SD–366, Dirksen Senate Office Building, Hon. Lisa Murkowski, Chairman of the Committee, presiding.

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

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

We have a full slate of witnesses this morning, so I want to get started here. We are beginning a hearing this morning on DOE's carbon capture, utilization, and storage programs, or CCUS. We are also considering S. 1201, the Enhancing Fossil Fuel Energy Carbon Technology Act, or the EFFECT, Act.

Senator Manchin, I have already given you great credit for coming up with great acronyms. EFFECT is pretty good. We appreciate that. I am proud to cosponsor it.

Senator MANCHIN. I am proud to have you.

[Laughter.]

The CHAIRMAN. This hearing is part of our Committee's ongoing discussion on clean energy innovation to address our changing climate.

In March, the Committee examined the impact of climate change in the electricity sector, and in both February and April we discussed opportunities for energy innovation. In those hearings and others, our witnesses made clear to us that significant reductions in greenhouse gas emissions will be a major undertaking that will require an all-of-the-above approach.

We are working on that approach now because we can see it. We can feel it. Climate change is with us every day, whether we like it or not, and whether or not we use the words climate change, it is there. Come to Alaska, I will show you diminishing sea ice, melting permafrost, more frequent extreme weather events, and rising

sea levels. We are warming in the State of Alaska at twice the rate of the Lower 48, and many villages are threatened by coastal erosion, with some needing out-and-out relocation. Our Committee recognizes the threat of climate change, so we have been hard at work on practical, bipartisan solutions to increase deployment of clean and innovative energy technologies.

In March, I introduced the Nuclear Energy Leadership Act along with 17 of my colleagues. And then earlier this week, we heard my American Mineral Security Act, and Senator Manchin's Rare Earth Element Advanced Coal Technologies, or REEACT. Both of these bills will help the U.S. rebuild its supply chain for clean energy technologies like electric vehicles (EVs), solar panels, and more.

The bill that we are here to consider today, the EFFECT Act, focuses on increased deployment of carbon capture, utilization, and storage technology, again referred to as CCUS. It is a natural complement to our work last Congress to expand the 45Q tax credit and it presents a tremendous opportunity to reduce our emissions while maintaining the availability of reliable electricity generation resources. Our bipartisan bill will help us seize that opportunity by expanding and modernizing DOE's research and development programs in this field.

We are seeing that CCUS technology can work. There are 18 large-scale facilities in commercial operation around the world that are already capturing and storing tens of millions of tons of carbon dioxide per year. Here in the U.S., NRG's Petra Nova project, located onsite at a coal-fired power plant, has an annual carbon dioxide capture capacity of 1.4 million tons. That is equivalent to removing the daily emissions from 350,000 cars.

There are many other promising projects in development. Project Tundra, a proposed project at a coal-fired power plant in North Dakota, aims to store up to 3.6 million tons of carbon dioxide per year. And the NET Power facility in development near Houston will utilize a process called the Allam Cycle to produce electricity from natural gas using zero carbon emissions. These are just a few examples of projects around the globe. In order for CCUS to have any meaningful impact on global emissions, however, many more of these facilities need to be deployed.

So today we are going to examine the state of CCUS technologies, the challenges of greater deployment, and how the Federal Government can be an effective partner to bring these technologies to market.

We have a very distinguished panel before us today. We have Assistant Secretary Steven Winberg from the Department of Energy (DOE). We have Dr. Julio Friedmann, who is a Senior Research Scholar at the Center for Global Energy Policy at Columbia University; Mr. Adam Goff is the Principal and Policy Director at 8 Rivers Capital; Mr. John Harju is the Vice President for Strategic Partnerships at the University of North Dakota's Energy and Environmental Research Center; Mr. Richard Jackson is a Senior VP for Operations Support at Occidental Petroleum Company; and Mrs. Judith Lagano, who is the Senior Vice President for Asset Management at NRG Energy.

So we have a great panel assembled for us this morning, and I am looking forward to hearing from them. But before we do, I will

turn to my colleague and friend, Senator Manchin, for your comments.

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

Senator MANCHIN. Thank you, Chairman Murkowski, and thank you so much for the gathering today to discuss carbon capture, utilization, and sequestration and the Enhancing Fossil Fuel Energy Carbon Technology, or the EFFECT Act.

The CHAIRMAN. Gotta love it.

Senator MANCHIN. I love it. It sounds good. We have to make it work now.

I thank all of you for coming here and sharing your expertise with us, and we look forward to the hearing and hope you are going to have comprehensive answers to some of these difficult questions and challenges that we have.

Earlier this year, Dr. Birol, of the non-partisan International Energy Agency, the IEA, told this Committee that CCUS should be the most critical technology in which we can invest. Likewise, in the models run by the U.N. Intergovernmental Panel on Climate Change for Stabilizing Emissions by 2050, many projected the need for carbon capture to achieve the below-two-degree-Celsius goal. The models without carbon capture show climate mitigation costs rising by 138 percent.

I really do think there is bipartisan agreement in Congress about the role CCUS will need to play in lowering the world's carbon emissions; but we have to put our money where our mouth is and enact strong policies that will help commercialize these technologies in the very near term. That is why I introduced the EFFECT Act last month with my dear friend, Chairman Murkowski, and a bipartisan group of Senators. It is a comprehensive bill that is aimed at enhancing research and development and, just as importantly, demonstration and deployment for each aspect of CCUS. That includes coal, natural gas technologies, utilization, storage, and even atmospheric CO_2 removal.

As we say in West Virginia, everything but the squeal. Have you all heard that saying? When you butcher the pig back home, I think in the hills of West Virginia, we eat everything but the squeal. Okay.

Now let's take a step back and take a look at the global picture. The IEA recently issued a report showing energy consumption around the world grew by 2.3 percent in 2018, with fossil fuels meeting nearly 70 percent of that increased demand. The average age of a Chinese coal plant is 12 years. They are going to be running those plants for years to come whether we like it or not. That is backed up by predictions that under current policies, 51 percent of China's power and 57 percent of India's power could come from coal in the next 20 to 30 years.

So if we acknowledge that fossil fuels are going to be part of the global energy mix—and we do call this the global climate, not the North American climate—for decades to come, then we need to figure out how to use them in the cleanest way we can.

It is a fact that our country has the greatest resource of all, brilliant researchers and entrepreneurs. Let's give them the direction

and the funding to do what they do best, because if we can lead in the CCUS space, then we can do a number of incredibly important things. First, we could maintain our affordable and reliable domestic energy supply. Second, we could export these technologies to those countries who show no sign of cutting off their use of fossil fuels and enable them to cut down on their emissions. Third, we can boost our economy with the utilization of CO_2, something previously valueless, either for enhanced oil recovery (EOR) as we're seeing now or for use in cement products, fuel, or any number of industrial settings.

Senator King has a good idea. It is a major bottling facility, and they use all the CO_2 for the fizz.

If we are thinking pragmatically, there should be no downside to supporting and accelerating CCUS deployment on a large scale, no matter where you are coming from on the political spectrum.

I would also like to briefly touch on one aspect of the EFFECT Act that is unrelated to coal or natural gas, and that is carbon removal.

Taking CO_2 right out of the air is something that former Energy Secretary Ernie Moniz and other luminaries are looking at, as are oil companies like Occidental Petroleum, who we will hear from today. And we thank you for that.

As I have said, we need to think of all the ways to skin this cat of that problem called climate change and aggressively pursue the options that can realistically help us meet our goal, and removing CO_2 directly from the ambient air is one of those things. It can be something as technologically complex as direct air capture or something as simple as afforestation. This includes the RD&D program for large-scale atmospheric removal of CO_2 which is the necessary companion to the RD&D for coal and natural gas technologies.

It will round out the full suite of technologies needed in the carbon capture space. This is the moonshot, and we need to get behind it and do it now.

We have a wide-ranging panel of witnesses before us today who can discuss CCUS from every perspective. I look forward to getting a status update and outlook from you all and hearing your feedback on the EFFECT Act, if you had a chance to look at it.

Before I turn back to you, Madam Chairman, I would like to enter these letters and statements of support for the EFFECT Act into the record from the Carbon Utilization Research Council, The Nature Conservancy, the International Brotherhood of Boilermakers, the Carbon Capture Coalition, the Clean Air Task Force and BPC Action.

Thank you, Madam Chair.

The CHAIRMAN. They will be included as part of the record.

[The information referred to follows:]

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CURC CARBON UTILIZATION RESEARCH COUNCIL
ADVANCING FOSSIL ENERGY SOLUTIONS

April 11, 2019

The Honorable Senator Joe Manchin
United States Senate
306 Hart Senate Office Building
Washington D.C. 20510

Dear Senator Manchin:

The Carbon Utilization Research Council (CURC) is pleased to support the Enhancing Fossil Fuel Energy Carbon Technology (EFFECT) Act of 2019. This legislation would provide an important update to the Fossil Energy Research and Development (FER&D) Program at the Department of Energy, modernizing the program to confront the unique challenge we face to address the effects of climate change while ensuring access to affordable, reliable electricity. The EFFECT Act would authorize additional federal investments in research, development, demonstration, and commercial application of advanced fossil fuel technologies, and CURC applauds your leadership in developing and introducing the legislation.

The United States must be a leader in developing a broad suite of energy technologies that have the potential to reduce greenhouse gas emissions. With domestic and international energy portfolios projected to include substantial long-term fossil fuel use, carbon capture is a crucial part of the equation. The International Energy Association (IEA) testified before the Senate Energy and Natural Resources Committee on the importance of U.S. leadership in the development of carbon capture technologies to address climate change.

CURC supports your recommendation that the U.S. embark on a "moonshot" initiative for carbon capture, and the EFFECT Act would be an important step in service of that mission. The program outlined in the legislation aligns with the recommendations made in the *2018 CURC-EPRI Advanced Fossil Energy Technology Roadmap* by making substantial investments in RD&D for carbon capture and storage technologies and authorizing funding for large-scale pilot and commercial demonstration projects. This kind of comprehensive federal support is critical to ensure that technologies are able to move from the basic research phase through to commercialization. The EFFECT Act also authorizes additional investments in front-end engineering and design studies and would direct the Department of Energy to study the viability of long-term stabilization support contracts – an effort CURC believes would be extremely valuable in demonstrating and financing commercial scale carbon capture projects.

A robust carbon capture RD&D program as proposed in the EFFECT Act also has the potential to unlock significant economic benefits for the U.S. A report commissioned by CURC and ClearPath, *Making Carbon a Commodity: The Potential of Carbon Capture RD&D*, found that such an accelerated RD&D program could enable the market-driven deployment of up to 87 GW of carbon capture, which could support up to 780,000 jobs and a $190 billion increase in GDP.

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Shannon Angielski

CURC CARBON UTILIZATION RESEARCH COUNCIL
ADVANCING FOSSIL ENERGY SOLUTIONS

In short, the EFFECT Act is critical piece of legislation that, if enacted, can lead to substantial environmental and economic benefits for the United States and maintain the U.S. leadership role in developing a technology that can combat global climate change. CURC appreciates your leadership in developing this legislation and your willingness to engage on the development of additional language that will address the effect of the technologies funded through this new program when applied in demonstration projects.

CURC is thrilled to support this legislation and we look forward to working with you to see it enacted in this Congress.

Sincerely,

Shannon Angielski

Shannon Angielski
Executive Director, CURC

The Nature Conservancy
Protecting nature. Preserving life.

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Jason Albritton
Director of Climate and Energy Policy
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April 12, 2019

The Honorable Joe Manchin III
Ranking Member
Committee on Energy and Natural Resources
US Senate
Washington, DC 20510

Dear Senator Manchin:

On behalf of The Nature Conservancy, I write to express our gratitude for your leadership in introducing the EFFECT Act (S. 1201). We are also thankful to Senators Murkowski, Capito, Cramer, and Daines who joined you as cosponsors of this legislation.

As a conservation organization, we are committed to finding common sense solutions to some of nature's greatest challenges, including climate change. Climate change is the most urgent threat facing our communities, our economy, and the land and waters upon which all life depends. We are already seeing the impacts of climate change on natural systems, on our food and water supplies, and on businesses. Reports from the United Nations and from the United States' own National Climate Assessment are clear that in order to avoid the worst impacts from carbon pollution, we need to act decisively and without hesitation.

Given the urgency of the problem, the Conservancy believes we must deploy all the tools at our disposal to reduce greenhouse gas emissions, and that includes using the power of nature to remove carbon from the environment while advancing the development of carbon capture, utilization, and sequestration technologies. We support efforts to ensure carbon capture technology is available as an effective tool for reducing greenhouse gas emissions while maintaining environmental safeguards.

Specifically, TNC appreciates the inclusion of a comprehensive carbon removal research and development program that will invest in advancing a wide array of carbon removal technologies, including maximizing the ability of forests and agricultural lands to store carbon. By investing in research and development for carbon capture and removal technologies, the EFFECT Act will play a critical role in helping these technologies come online faster and more effectively.

We appreciate the bipartisan leadership on this issue and look forward to working with you and other members of the Senate as this legislation moves forward.

Sincerely,

Jason Albritton

cc: Senator Lisa Murkowski
Senator Shelley Moore Capito
Senator Kevin Cramer
Senator Steve Daines

International Brotherhood of
BOILERMAKERS • IRON SHIP BUILDERS **BLACKSMITHS • FORGERS & HELPERS**

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May 14, 2019

The Honorable Lisa Murkowski
Chairman
Senate Committee on Energy and
Natural Resources
522 Hart Senate Office Building
Washington, D.C. 20510

The Honorable Joe Manchin
Ranking Member
Senate Committee on Energy and
Natural Resources
306 Hart Senate Office Building
Washington, D.C. 20510

Dear Chairman and Ranking Member,

On behalf of the International Brotherhood of Boilermakers, Iron Ship Builders, Blacksmiths, Forgers and Helpers (Boilermakers), I would like to offer our strong support for S.1201, the Enhancing Fossil Fuel Energy Carbon Technology Act of 2019 (EFFECT Act).

The Boilermakers have long advocated for robust federal investments in the development and wide deployment of Carbon Capture, Utilization and Storage (CCUS) technologies as a necessary and common-sense response to curbing carbon dioxide emissions, both in the U.S. and around the globe. As we face a carbon-constrained future, we need investments that protect economic growth and energy diversity, while making critical advances in new technology that will create jobs. When commercially available, the deployment of CCUS will create countless man-hours for Boilermakers and other union crafts invested in the energy and industrial sectors.

Both the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) have identified CCUS as a major component in responsibly decarbonizing not only the utility sector, but also hard-to-abate sectors, such as cement and steel. With adequate investments, the United States can be a true global leader in developing this important climate and energy solution.

We would also like to bring to your attention "CCS: Bridge to a Cleaner Energy Future" - an initiative underwritten by the Boilermakers to engage the global community in a conversation about the vital role carbon capture and storage (CCS) must play in mitigating climate change. The film was shot in Vancouver, British Columbia, in March 2018, during the GLOBE Leadership Summit for Sustainable Business. We would be honored if you and your fellow committee members would view our piece at https://www.cleanerfutureccs.org/.

We commend you for your bipartisan leadership in introducing this important legislation. We look forward to working with you and your staff to enact this urgently needed expansion of federal investment in CCUS to bring down emissions, foster job creation and promote business opportunities in the management and beneficial use of carbon.

Sincerely,

Cecile M. Conroy
Director, Government Affairs

cc: Newton B. Jones, International President
William T. Creeden, International Secretary-Treasurer
U.S. International Vice Presidents



CARBON CAPTURE COALITION

Carbon Capture Coalition Commends Senate Introduction of the EFFECT Act

April 11, 2019/Legislation

The Carbon Capture Coalition commends the introduction in the U.S. Senate today of the Enhancing Fossil Fuel Energy Carbon Technology (EFFECT) Act. The legislation was introduced by Senators Joe Manchin (D-WV), Lisa Murkowski (R-AK), Shelley Moore Capito (R-WV), Kevin Cramer (R-ND) and Steve Daines (R-MT). Coalition co-directors Jeff Bobeck and Brad Crabtree issued the following statement:

"The Carbon Capture Coalition applauds the introduction of the Enhancing Fossil Fuel Energy Carbon Technology (EFFECT) Act to expand and retool the Department of Energy's fossil energy research, development and demonstration (RD&D) objectives and programs as vitally importan legislation to help meet the challenge of reducing our nation's carbon emissions and sustaining U.S. global leadership in carbon capture, utilization, storage and removal technologies.

"The most recent report from the Intergovernmental Panel on Climate Change (IPCC) found that if global emissions reductions goals are to be met, investments in low-carbon energy technology and energy efficiency will need to increase by roughly a factor of five by 2050, compared to 2015 levels. The EFFECT Act responds to this challenge by authorizing five new programs to develop transformational technologies, including research and development, large-scale pilot projects, demonstration projects, and front-end engineering and design. These investments in the development and demonstration of transformational carbon capture utilization, storage and removal technologies will be a critical component of driving down costs to accelerate commercial deployment, just as previous federal RD&D investments have helped accomplish with other low and zero-carbon energy technologies.

"The Coalition commends Senators Manchin, Murkowski, Capito, Cramer and Daines for their bipartisan leadership in introducing this legislation. We look forward to working with Congress to enact this urgently needed expansion of federal investment in carbon capture, utilization, storage and removal to bring down emissions, foster job creation and promote business opportunities in the management and beneficial use of carbon."



CLEAN AIR
TASK FORCE

The Clean Air Task Force supports Senators Manchin and Murkowski in their efforts to expand support for transformational carbon capture utilization and storage technologies in the proposed Enhancing Fossil Fuel Energy Carbon Technology Act. CATF supports the bill's goal of creating four new programs to further develop transformational CCUS technologies for coal- and gas-fueled power and industrial sources, including research and development, large-scale pilot projects, demonstration projects, and front-end engineering and design. Carbon capture and storage technologies have been in commercial use for decades, but only recently have they been used for the purpose of reducing carbon dioxide emissions. Just as was the case with wind and solar technologies in the 1990s, learning by doing and transformational technology investment are the keys to further reducing the cost of CCS projects. Therefore, increased research, development and demonstration, focused on transformational technology, is an important compliment to the recently adopted 45Q tax credit, which will help drive learning and cost declines through additional deployment.

Kurt Waltzer

Managing Director

Clean Air Task Force

BPC Action applauds **Senate Energy Committee Chair Murkowski (R-AK)** and **Ranking Member Manchin (D-WV)** for introducing the **Enhancing Fossil Fuel Energy Carbon Technology Act** (the EFFECT Act). The EFFECT Act would facilitate greater development and deployment of advanced carbon removal and carbon capture technologies to achieve economic growth and emission reductions.

Importantly, the bill provides incentives for transformational and large-scale carbon capture, utilization, and storage projects to stimulate further technology advances in this space and establishes a dedicated research program for carbon removal. The bill also authorizes a vital prize competition for direct air capture technologies that remove carbon dioxide from dilute sources such as the atmosphere on a significant scale.

As nations increasingly seek to decarbonize their economies, carbon removal and carbon capture, utilization, and storage technologies are imperative to reduce carbon pollution. Global energy demand is expected to grow substantially over the next several decades and fossil fuels are projected to retain a significant role in meeting these needs. A portfolio of low-, zero-, and negative-carbon technologies will be needed to achieve global emission reduction targets while making our economy cleaner, more efficient, and more competitive worldwide.

BPC Action looks forward to working with Congress to pass this important legislation

The CHAIRMAN. Thank you, Senator.

Senator Hoeven, I understand you would like to do a little bit further introduction of Mr. Harju?

STATEMENT OF HON. JOHN HOEVEN,
U.S. SENATOR FROM NORTH DAKOTA

Senator HOEVEN. I would, thank you, Madam Chairman and Ranking Member Manchin. I appreciate that very much.

I know him extremely well and he is a great guy, so I could just brag on him without reading my notes, but then he has all these amazing accomplishments and they are way above my head so I have to read that part because otherwise I would totally screw it up. So I am going to read for a while. But he is a good friend. He is a good friend.

[Laughter.]

And he is really, really smart, Joe, you know, a smart guy.

Senator MANCHIN. John, we have all the smart ones here today.

Senator HOEVEN. Yes, they look like it.

So again, thanks to both of you and I do appreciate the opportunity to talk a little bit about John Harju.

He is a University of North Dakota graduate, Vice President for Strategic Partnerships at the EERC, which is the Energy and Environmental Research Center. I think, Madam Chairman, I have had you out there, haven't I, to the EERC? They do amazing stuff. And he just brings a wealth of experience in CCUS technology. I am getting all excited because I remember when it was CCS and now it is CCUS. Utilization, I guess, got added in there. Was that new with the addition of the Ranking Member to this?

Senator MANCHIN. Utilization, if we could utilize it better than sequester it——

Senator HOEVEN. Well, I will tell you what, you better tell King it is going to take a lot of bottles and a lot of fizz, if that is what we are——

Senator MANCHIN. He is right.

Senator HOEVEN. One example of John's ability to collaborate is his efforts to grow the Plains CO_2 Reduction Partnership, PCOR, which is one of seven regional carbon sequestration partnerships awarded by the Department of Energy. Under his leadership, PCOR has grown to include more than 100 U.S. and Canadian stakeholders, and in that endeavor they secure a minimum of 20 percent cost share from all our non-federal partners.

I should mention, too, that with the Dakota Gasification Plant, we are stripping CO_2 off of the process whereby we convert coal to synthetic natural gas. We are sending that CO_2 in a huge pipeline, compressed and liquified under real cold temperature. It goes to the Weyburn Oil Fields in Saskatchewan, Canada and it goes down a hole for tertiary recovery. They are doing that on a commercially successful basis right now which, of course, is what we have. That is what today is all about. That is where we have to get to. We can't just do it up in North Dakota and Saskatchewan, we have to do it all over the world, right? That is what today is all about.

So this really reflects our all-of-the-above approach—in this case, CCUS technology, applying that technology to coal-fired plants.

I am going to want to talk particularly to the Honorable Steven Winberg about some projects we are working on. Project Tundra which is post combustion and the Allam Cycle which would be building a new plant. And we have John here to just keep you honest and make sure whatever you tell us is the straight stuff, because he really knows this stuff.

I am teasing him obviously, but he is, I am not teasing about the fact that he is deeply, deeply immersed into this stuff, the way we have to be.

It is not about getting to technological feasibility, you all can do it. It is about getting to commercial viability.

So again, John, thanks for being here and for all your great work. But to all of you, thanks for being here and for your great work.

Madam Chairman, thank you for your indulgence. I appreciate it very much.

The CHAIRMAN. Thank you. We do appreciate not only the expertise that Mr. Harju brings but that all of you do. So we are looking forward to your testimony here this morning.

Mr. Winberg, we will begin with you. I ask you all to try to limit your comments to about five minutes, and your full statements will be included as part of the record. Then we will have an opportunity for the back and forth afterwards.

Mr. Winberg, welcome.

STATEMENT OF HON. STEVEN E. WINBERG, ASSISTANT SECRETARY FOR FOSSIL ENERGY, U.S. DEPARTMENT OF ENERGY

Mr. WINBERG. Thank you, Chairman Murkowski, Ranking Member Manchin and members of the Committee.

With the Committee's ongoing support, we are backing up our commitment to CCUS with the R&D necessary to advance these technologies, improve our environmental footprint and advance U.S. world leadership in this critical area.

With respect to S. 1201, the Enhancing Fossil Fuel Energy Carbon Technology Act of 2019, the Administration is currently reviewing this legislation. I look forward to answering any questions you may have on the legislation. As always, the Administration is ready to provide technical assistance, as needed, on this legislation, moving forward.

The American taxpayer has invested nearly $4 billion in CCUS since 2010. We are approaching the point at which the American taxpayer will receive return on this investment.

Just over the horizon, we see energy generation technologies that can deliver electricity with near-zero greenhouse gas emissions at some of the lowest costs in the world. We also see a robust enhanced oil recovery industry that can produce oil with 37 percent less CO_2 emissions on a life-cycle basis.

So far this fiscal year, the Fossil Energy Office of DOE has selected carbon capture technology projects totaling $24 million; we've announced $30 million for front-end engineering and design studies for capture systems on both coal and natural gas plants; we've announced $20 million for a regional initiative to accelerate CCUS; and we plan to release a $30 million Funding Opportunity

Announcement (FOA) for large-scale CO_2 storage projects through DOE's CarbonSAFE initiative that is focused on the development of geological storage sites for CO_2. We've selected multiple projects, totaling $13 million, to develop innovative methods for converting CO_2 into valuable products and chemicals through our Carbon Utilization program, and we've launched the Coal FIRST initiative to develop the coal plant of the future to provide secure, stable, reliable power with near-zero emissions, including CO_2. These plants will be flexible. They'll be innovative. They'll be resilient, small and transformative.

Commercializing and deploying CCUS technologies is a realistic path to addressing CO_2 on a large scale. Funding provided by Congress through the Fossil Energy Office has resulted in the commercial operation of the world's three largest CCUS demonstration projects—Petra Nova, Air Products and Archer Daniel Midland. These projects already have captured, utilized and stored almost nine million metric tons of CO_2.

Fossil Energy's robust CCUS R&D program has produced some impressive results like these demonstration projects, but the most significant hurdle is the cost associated with carbon capture which we aim to reduce by 50 percent to $30 a metric ton by 2030. This is a challenging goal but with Fossil Energy's R&D and the 45Q tax credit, we have the potential to reach that cost reduction target.

One important element of Fossil Energy's R&D effort is direct air capture which is aimed at improving capture efficiency, reducing energy and capital cost and lowering water resource demands by leveraging our $4 billion investment on CCUS technologies.

Fossil Energy is performing exploratory research in this area and currently has three direct air capture research projects. Fossil Energy's CO_2 capture expertise creates an opportunity to work toward DAC commercialization, or Direct Air Capture.

So we appreciate the Committee's interest, support, and commitment to provide DOE with the tools necessary to advance CCUS technologies, and I look forward to answering your questions.

Thank you.

[The prepared statement of Mr. Winberg follows:]

Testimony of Steven E. Winberg
Assistant Secretary for Fossil Energy
U.S. Department of Energy

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

Examining the U.S. Department of Energy's Carbon Capture, Utilization and Storage Programs and Receive Testimony on S.1201, the Enhancing Fossil Fuel Energy Carbon Technology Act of 2019

May 16, 2019

Thank you, Chairman Murkowski, Ranking Member Manchin, and Members of the Committee. I appreciate the opportunity to be here today, and it is my pleasure to appear before you to discuss how the Department of Energy (DOE) is advancing an important part of DOE's Fossil Energy (FE) research and development (R&D) portfolio — the commercial deployment of carbon capture, utilization, and storage (CCUS) technologies. With the Committee's ongoing support, we are backing up our commitment to CCUS with the R&D necessary to advance these technologies, improve our environmental footprint, and advance U.S. world leadership in this critical area.

The American taxpayer has invested nearly $4 billion in CCUS since 2010. We are approaching the point at which the American taxpayer will receive return from this investment. Just over the horizon, we see energy generation technologies that can deliver electricity with near-zero greenhouse gas (GHG) emissions at some of the lowest costs in the world. We also see a robust enhanced oil recovery (EOR) industry that can produce oil with 37 percent less CO_2 emissions on a life-cycle basis.

So far this fiscal year we have:

- Selected carbon capture technology projects totaling $24 million;
- Announced $30 million for front-end engineering and design (FEED) studies for capture systems on both coal and natural gas power plants;
- Announced $20 million for a regional initiative to accelerate CCUS, and we plan to release a $30 million Funding Opportunity Announcement for large-scale CO_2 storage projects through DOE's CarbonSAFE initiative that is focused on the development of geologic storage sites for CO_2;
- Selected multiple projects, totaling $13 million, to develop innovative methods for converting CO_2 into valuable products and chemicals through our Carbon Utilization program; and

- Launched the Coal FIRST (Flexible, Innovative, Resilient, Small, Transformative) initiative to enable industry to develop the coal plant of the future, which will provide secure, stable, reliable power with near-zero emissions, including CO_2. This early-stage R&D will support the development of coal-fired power plants that are capable of *flexible* operations to meet the needs of our evolving grid; use *innovative* and cutting-edge components that improve efficiency and reduce emissions; provide *resilient* power to Americans; are *small* compared to today's conventional utility-scale coal to meet the needs of distributed generation; and will *transform* how coal technologies are designed and manufactured.

Fundamental changes to the operating and economic environment in which coal plants function are expected to persist into the next decade and beyond. Deployment of new coal plants will require a different way of thinking. The need for dispatchable generation, critical ancillary services, grid reliability and energy security, such as the importance of onsite fuel availability during extreme weather events, creates an opportunity for advanced coal-fired generation both domestically and internationally. Right now, though, there is a pressing need to develop and implement policies that will provide financing and market certainty to support the development of CCUS supply chains, commercial infrastructure, and private sector investment.

With respect to S. 1201, the Enhancing Fossil Fuel Energy Carbon Technology Act of 2019, the Administration is currently reviewing this legislation and no position has been taken on this bill. S. 1201 directs the Department of Energy to support four programs focused on fossil energy R&D and carbon capture, utilization, and storage:

- A Coal and Natural Gas Technology Program to support large-scale pilot projects, demonstration projects, and the "development of technologies to improve the efficiency, effectiveness, costs, and environmental performance of coal and natural gas use."

- A Carbon Storage Validation and Testing Program to conduct research, development, and demonstration projects for carbon storage and establish a large-scale carbon sequestration demonstration program, with the possibility of transitioning to an integrated commercial storage complex.

- A Carbon Utilization Program to identify and assess novel uses for carbon, carbon capture technologies for industrial systems, and alternative uses for coal.

- A Carbon Removal Program for technologies and strategies to remove atmospheric carbon dioxide on a large scale.

As always, the Administration is ready to provide technical assistance as needed on this legislation moving forward.

All informed experts agree, commercializing and deploying CCUS technologies is a realistic path to reducing CO_2 emissions on a large scale. An integral piece to "jumpstart" this

deployment is financial incentives, such as section 45Q of the Internal Revenue Service code, which provides a tax credit on a per-ton (metric) basis for storing or utilizing captured CO_2. DOE is currently working with the Internal Revenue Service, the Department of the Treasury, the Department of the Interior, and the Environmental Protection Agency to resolve uncertainties regarding implementation.

FE's robust CCUS R&D program has produced some impressive successes, but technical hurdles to commercializing these technologies remain. The most significant hurdle is the cost associated with carbon capture, which needs to be reduced by about 50 percent to $30 a metric ton by 2030 to be competitive with alternative energy sources. That is a challenging goal, and we have made great progress by exploring early-stage R&D on advanced technologies that have the potential to reach our cost reduction goals.

Over the last four decades, DOE has demonstrated a proven track record in significantly reducing emissions from fossil fuel combustion, resulting in a cleaner environment for all Americans. The technologies developed through this R&D program are not only applicable to coal and natural gas-fired power plants, but can also be used with industrial sources such as refineries and steel, cement, chemical and ethanol plants. These technologies can be used to capture CO_2 directly from the atmosphere.

Funding provided by Congress through FE has resulted in commercial operation of the world's three largest CCUS demonstration projects in their respective industrial sectors (Petra Nova, Air Products, and Archer Daniels Midland). In total, these projects have captured, utilized, and stored almost 9 million metric tons of CO_2.

- Petra Nova: Retrofitted onto the existing W.A. Parish coal-fired unit 8, the 240-megawatt Petra Nova project near Houston, Texas, captures approximately 90 percent of the CO_2 from the unit's flue stream and permanently stores about 1.4 million metric tons of CO_2 per year for EOR in a depleted oil field approximately 80 miles away. As of March 2019, Petra Nova has captured and sent for storage over 2.4 million metric tons of CO_2, and West Ranch Oil Field has produced over 2.8 million barrels of oil through EOR.

- Air Products: The Air Products and Chemicals project at a petroleum refining facility in Port Arthur, Texas, captures over 90 percent of the CO_2 produced from the two steam methane reformers for hydrogen production. Air Products has successfully captured and stored over 5 million metric tons of CO_2 for EOR.

- Archer Daniels Midland: The Archer Daniels Midland Company project near Decatur, Illinois, demonstrates an integrated system for capturing CO_2 from an ethanol production plant and geologically sequestering it in the Mount Simon Sandstone formation – one of the largest saline reservoirs in the world for CO_2 storage. As of April 2019, 1.2 million metric tons of CO_2 have been injected into the Mount Simon Sandstone.

DOE's FY 2020 budget represents a purposeful shift away from later-stage R&D such as development and scale-up of 2nd generation capture technologies to prioritize early-stage

research and development to reflect the proper role of the Federal Government. Industry is better positioned to make decisions on what technologies can be commercialized and how to develop and scale these technologies for cost-competitive deployment.

One important element of FE's R&D effort is Direct Air Capture (DAC). FE was one of the co-funders of the recent National Academy of Sciences (NAS) report on developing a research agenda for negative emissions technologies, which included DAC. The focus of DAC R&D is on improving capture efficiency, reducing energy and capital costs (current cost estimates range between $200–$800/ton CO_2), and decreasing water resource demands. FE is conducting techno-economic analyses to establish a cost baseline for DAC technologies, and is funding exploratory research studies in this area. FE currently has three DAC R&D projects with:

1. Ohio State University – "Novel Carbon Dioxide (CO_2) – Selective Membranes for CO_2 Capture from less than 1% CO_2 Sources";
2. Carbon Engineering, Ltd. – "Dilute Source Carbon Dioxide (CO_2) Capture: Management of Atmospheric Coal-Produced Legacy Emissions"; and
3. InnoSepra, LLC – "Process for CO_2 Capture from Low Concentration Sources."

DAC technologies (e.g., advanced sorbents, membranes, and solvents) are built upon FE's R&D and are adapted to address issues specific to DAC, such as accelerating reaction kinetics. Existing resources in the FE program can be leveraged to develop new materials and design processes specific to DAC, optimize DAC performance using advanced supercomputers, and validate laboratory R&D through pilot-scale testing. FE takes a holistic approach to DAC-specific R&D by developing the technologies, system(s), logistics, and cost reductions to make DAC implementation a reality. Further, FE recognizes the important role that stakeholders play in this area and is planning a workshop later this year to strengthen that engagement. Low concentrations of CO_2 associated with DAC create unique challenges, but FE's 19-plus years of CO_2 capture expertise will help commercialize DAC.

In addition to DAC R&D, FE is also investigating ways to extract an economic benefit, or additional value, from the captured CO_2 through the development of products and services. For example, FE is working on CO_2 utilization as a feedstock for commonly used chemicals such as methanol, synthetic fuels, and baking soda, as well as advanced materials like improved concrete and carbon fiber. While EOR is the most near-term application of CO_2, the development of these advanced materials offers opportunities to monetize the captured CO_2 and drive domestic innovation.

In the area of Carbon Storage, DOE's goal is to better see the subsurface to improve site selection for geologic storage of CO2; improve CO2 storage and utilization efficiency for enhanced oil recovery; and increase the certainty of secure containment and environmental protection. Previous investments in an initiative called the Regional Carbon Sequestration Partnerships identified CO2 sources and sinks on a regional basis throughout the country and conducted large-scale injection projects. This resulted in over 10 million metric tons of CO2 stored. The work from this effort has been captured in Best Practice Manuals to disseminate that knowledge to industry partners.

Since 2016 DOE has invested over $70 million in the CarbonSAFE initiative, which builds on findings from pilot and field demonstration projects to advance site selection and storage operations at commercial-scale. There are currently six active CarbonSAFE projects regionally distributed throughout the US to determine the feasibility for commercial-scale storage complexes that can store greater than 50 million metric tons of CO2.

We appreciate the Committee's interest, support, and commitment to providing DOE with the tools necessary to advance CCUS technologies, and I look forward to answering any questions you may have.

Thank you.

The CHAIRMAN. Thank you, Mr. Winberg.
Dr. Friedmann, welcome.

STATEMENT OF DR. S. JULIO FRIEDMANN, SENIOR RESEARCH SCHOLAR, CENTER ON GLOBAL ENERGY POLICY, COLUMBIA UNIVERSITY SCHOOL OF INTERNATIONAL & PUBLIC AFFAIRS

Dr. FRIEDMANN. Chairman Murkowski, Ranking Member Manchin, members of the Committee, Senator Barrasso, Senators Hoeven, King and Cortez Masto, it's a real treat to be here. Thank you for inviting me to discuss the EFFECT Act and the DOE CCUS programs.

I'm Dr. Julio Friedmann. I'm the Senior Research Scholar at Columbia's University Center on Global Energy Policy.

It's an honor to appear before this Committee. Since my last Congressional testimony, the world has changed a lot. Analysis from the IPCC and dozens of other organizations conclude that CCUS is required; it's essential to achieve important climate targets, including two degrees, much less one and a half degrees. In fact, without CCUS most models do not converge on a solution at all. Those that do cost more than twice as much to reach the same target. That's why the Center for Global Energy Policy has launched the Carbon Management Research Initiative which I lead.

The world of CCUS has also changed, even in a year. Today 18 projects worldwide, including one in China, prevent 34 million tons of CO_2 from entering the air. The U.S. hosts eight of these facilities, the most of any country. More are on the way, in part, because of policies enacted by the House and Senate, notably the 45Q amendment under the Future Act. In short, you can't do CCUS without the U.S.

Groups like the IEA, Global CCS Institute and others underscore how CCUS is an essential approach to support both economic growth and rapid deep decarbonization. Many countries have added CCUS to their climate and energy plans. This includes new projects in China, Norway and the Middle East and new policies imperatives in the U.K., the Netherlands and Canada. It should now be clear to all that CCUS is not some untested technology or green washing or license to pollute. Quite the opposite, it is an overt, committed pathway to deeply and quickly reducing greenhouse gas emissions in a cost-effective way.

From 2013–16, I served as Principal Deputy Assistant Secretary for the DOE's Office of Fossil Energy and had the great pleasure of working with the people there who Steve Winberg currently has the great pleasure of working with and managing.

At the time we began to rethink our R&D portfolios driven by the profound shifts in U.S. and global energy markets. To respond to these shifts, we instituted changes in the R&D program in partnership with the National Energy Technology Lab in the great State of West Virginia: We decreased focus on coal gasification and increased focus on advanced power cycles, including things like NET Power's Allam Cycle; we shifted from broad geological assessments in the regional partnerships toward site specific focus for regions through the CarbonSAFE program; we helped launch and lead two cross-cutting R&D programs, the Supercritical CO_2 and

the SubTER initiatives; we began to explore issues and opportunities for applying CCUS to industrial facilities, not just power facilities; we scaled up our program on CO_2 conversion, and we issued the first grants on CO_2 removal and direct air capture. One of those grants to Carbon Engineering led to $68 million of private investment in the last year.

It soon became clear, not only would these new efforts prove important, but that also additional programs with additional funding would be necessary. If this sounds familiar, it's because they're embodied in the framework of the EFFECT Act. Although basic research remains important, both the maturity of CCUS and the urgency of climate change require us to emphasize applied R&D, large pilots and ultimately demonstrations.

My office was hampered by Congressional language which limited our ability to spend money based on fuel type. Both coal and gas are important parts of the U.S. energy system and biomass, increasingly, will be. All require carbon management and CCUS to serve broad public interests. In a carbon constrained world, in a carbon constrained economy, we have to emphasize our mission more than our fuels.

The U.S. has substantially underinvested in advanced technology options for heavy industry, including ways to reduce carbon pollution. Heavy industries like steel, cement, refining, petrochemicals and others are essential to the U.S. economy; they also represent 21 percent of our emissions. A new innovation thrust would help create clean, muscular U.S. heavy industry.

As I mentioned before, the CarbonSAFE program helps to identify and de-risk possible storage sites by providing site specific knowledge and data to potential operators. Already, CarbonSAFE has begun to unlock private capital investments and potential CCUS projects and more are on the way.

Technology advancement, low cost, abundant clean power and the harsh mathematics of climate change urgency have revealed CO_2 removal and CO_2 recycling to be both viable and essential, including technologies of direct air capture, CO_2 mineralization and converting CO_2 to products like cement and fuels.

All of these imperatives are represented in the EFFECT Act. I see it to be very similar to the SunShot Initiative which helped focused innovation on solar power and contributed substantially to cost reductions in those fields.

That said, the EFFECT Act alone will not bring CCUS to market. Additional policies are needed to accelerate deployment and align markets. I've listed all of that in my full testimony and I look forward to your questions.

Thank you very much.

[The prepared statement of Dr. Friedmann follows:]

COLUMBIA | SIPA
Center on Global Energy Policy

May 16, 2019

Congressional Testimony of
Dr. S. Julio Friedmann
Senior Research Scholar, Center on Global Energy Policy, Columbia Univ. School of International & Public Affairs

Before the
Committee on Energy and Natural Resources
United States Senate
2nd Session, 115th Congress

Chairman Murkowski, Ranking Member Manchin and Members of the Committee, thank you for inviting me here today to discuss the EFFECT Act and the Dept. of Energy's CCUS programs. My name is Julio Friedmann. I am a Senior Research Scholar at Columbia University's Center on Global Energy Policy at the School of International and Public Affairs.

It is an honor to appear again before this Committee to discuss CCUS, and timely. Since my last congressional testimony, the world has changed dramatically. Analysis from the Intergovernmental Panel on Climate Change and dozens of other organizations conclude that CCUS is essential to achieve important climate targets, including 2°C, let alone 1.5°.[1] In fact, without CCUS most models do not converge on a solution at all. Those that do cost more than twice as much to reach the same targets. That's why the Center for Global Energy Policy[2] has launched the Carbon Management Research Initiative,[3] which I direct. The Initiative draws on the extraordinary capabilities of Columbia Univ., including centers like the Earth Institute, Sabin Law Center, and faculty like Peter Keleman, Alissa Park, Bruce Usher, and Peter deMenocal.

The world of CCUS has also changed.[4] Today, eighteen CCUS projects operate worldwide and prevent 34 million tons CO_2 from entering our air and oceans every year. Eight of these, the largest number for any country, are in the US. More are on the way, in part because of policies enacted by

[1] IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, 32 pp.
https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/SR15_SPM_version_stand_alone_LR.pdf
[2] Center for Global Energy Policy website: https://energypolicy.columbia.edu
[3] Carbon Mgmt. Research Initiative Website: https://energypolicy.columbia.edu/carbon-management-research-initiative
[4] Global CCS Institute, 2018, Global Status of CCS Report,
https://www.globalccsinstitute.com/resources/global-status-report/

House and Senate, notably the 45Q amendments under the FUTURE act.[5] New projects, stimulated by these new laws, have been announced and more will be announced soon.

New studies by groups like the International Energy Agency,[6] Global CCS Institute, and the Energy Transition Commission[7] have underscored how CCUS is an essential component to supporting both economic growth and rapid, deep decarbonization. Many groups, ranging from Green New Deal advocates to the US Chamber of Commerce and all major oil companies, have stated strongly that man-made climate change is an urgent threat requiring more ambition and action. Many countries have added CCUS to their climate and energy action plans. This includes new projects in China, Norway, and the Middle East; formal announcement of CCUS policy imperatives in the UK, Netherlands, and Canada; and highlighting of CCUS at the pending Clean Energy Ministerial in Vancouver later this month.

It should be clear from all of this that CCUS deployment is not some untested technology or greenwashing or a license to pollute. Quite the opposite – it is an overt, committed pathway to deeply and quickly reduce GHG emissions in a cost-effective way while sustaining economic growth and communities at risk.[8]

My testimony will focus on how the policies like the EFFECT Act[9],[10] (Enhancing Fossil Fuel Energy and Carbon Technologies) and government agencies like the US Dept of Energy can help the US maintain leadership, sustain jobs and communities, innovate quickly, and rapidly reduce carbon pollution. While additional policy, investment and action will be needed, the EFFECT Act could be an important component of success if enacted.

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[5] Energy Futures Initiative, 2018, Advancing large scale carbon management: Expansion of the 45Q tax credit, EFI Report, 26 p.
https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5b0604f30e2e7287abb8f3c1/1527121150675/45Q_EFI_5.23.18.pdf

[6] International Energy Agency (IEA), *World Energy Outlook 2018*, November 2018.

[7] Energy Transition Commission, 2018, Mission possible: Reaching near-zero emissions from harder-to-abate sectors by mid-century, www.energy-transitions.org

[8] IEA op cit.; IEA, 2016, 20 years of CCS – Accelerating future deployment, 115p.
https://webstore.iea.org/20-years-of-carbon-capture-and-storage

[9] US Senate, 2019, EFFECT Act, fact sheet:
https://www.energy.senate.gov/public/index.cfm?a=files.serve&File_id=9B383CA2-97EF-4C61-93A6-60B740BFC2B0

[10] US Senate, 2019, EFFECT Act, full text
https://www.energy.senate.gov/public/index.cfm?a=files.serve&File_id=8AA33DF3-3527-4440-8D32-722B51CE3D30

From 2013-2016, I served as Principal Deputy Assistant Secretary for the Office of Fossil Energy at DOE. That experience led me to better understand the value of that Office's mission and those of the other Applied Energy offices. Importantly, well oriented and aligned R&D helps lay the foundation for scale-up through private investment and market deployment. At that time, we began rethinking the R&D portfolio within the Office of Fossil Energy, driven by the profound shifts in US and global energy markets; the incredible scale-up of US unconventional oil and gas production, export of LNG and crude oil, passage of the Paris Accords, and the stunning reduction in renewable energy prices. To respond to these dramatic shifts while serving the public, we instituted changes in the substance and direction of our R&D programs, in partnership with the National Energy Technology Lab:

- We decreased focus on coal gasification and increased focus on advanced power cycles, like NetPower's Allam Cycle.
- We shifted from broad geological assessments and knowledge building in the Regional Partnerships toward a site-specific focus for regions through the CarbonSAFE program.
- We helped launch and lead two cross-cutting R&D programs: supercritical CO_2 & SubTER.
- We began to explore issues and opportunities for application of CCS on industrial facilities and on modular chemical synthesis.
- We scaled up our program on CO_2 conversion and issued the first grants on CO_2 removal and direct air capture.

To ensure that our new directions would prove useful and valuable, we engaged industry, academic leaders, National labs, our international counterparts, and governmental leaders. It soon became clear not only would these new efforts prove important, but also that additional programs with additional funding would prove necessary. These required both an expansion of the identified lines and also new programs focused on large pilots, ultimately leading to a reimagined program of demonstration projects.

It also became clear that the primary task was improved environmental stewardship, chiefly in reducing CO_2 emissions. That remained true regardless of the fuel source (coal, gas, biomass) or application (power or heavy industry). To accomplish this mission, we needed to extend well beyond benchtop research and bring technologies and clean energy systems close to market.

If any of these themes sound familiar, perhaps it is because most are embodied formally in the framework of the EFFECT Act:

- Although basic research remains important, both urgency and maturity of CCUS systems require us to emphasize applied R&D, large pilots, and demonstration – RD&D. It's time to expedite deployment. With that framework, new authorization for efforts in large-scale

pilots, EFFECT act provisions that support front-end engineering design (FEED) and ultimately demonstrations are exactly the right work to undertake.

- My office was hampered by congressional language limiting our ability to spend R&D money based on fuel type. We should emphasize mission more and fuels less. Both coal & gas are important parts of the US energy systems, and biomass will be. All require carbon management and CCUS to serve broad public interests in a carbon constrained economy. China's reluctance to receive recycling or petroleum coke, and the IMO's new standards for maritime fuels, will likely bring more bitumen, municipal wastes, and other carbon intensive fuels into US and global markets. The EFFECT Act would lift this limitation.
- The US has underinvested in advanced technology options for heavy industry, including ways to deeply reduce carbon pollution. Heavy industry, including the manufacturing of steel, cement, refining, petrochemicals, fertilizer, and glass, is essential to the US economy and national security. It remains a major emitter of criteria pollutants and represent 21% of US GHG emissions in 2017. Industry is a major employer, notably for organized labor and underserved minorities, and could jeopardized by international border tariffs based on carbon content. A new innovation focus on clean heavy industry would help maintain a muscular US heavy industry, help us remain globally competitive, and could prove the cornerstone for future infrastructure and jobs investments. Doing so would also reduce conventional pollution, improving the quality of life for those living near such facilities and strengthening our national commitment to environmental justice.
- As mentioned before, the CarbonSAFE program helps to identify and de-risk potential CO_2 storage sites. In many cases, companies, municipalities, and states who wish to launch a CCUS project lack the site-specific knowledge and data to conscience necessary investments. Already, this program has begun to unlock private investment in potential projects that harness policies like 45Q, state zero-emission power standards, and the CA low-carbon fuel standards. Early geoscientific characterization and de-risking is important and required public funds to help overcome key hurdles for private investment.
- Technology advancement, low-cost abundant clean power, and in part driven by the harsh mathematics of climate change urgency, have revealed CO_2 removal to be essential. In addition, rapid technological progress in CO_2 conversion and use (also called carbon utilization or CO_2 recycling)[11] and in CO_2 removal[12] has created opportunities unimaginable

[11] Sandalow D. et al., 2017, Carbon Dioxide Utilization (CO2U): ICEF Roadmap 2.0, Innovation for A Cool Earth Forum, Roadmap Series, 56 p. https://www.icef-forum.org/pdf2018/roadmap/CO2U_Roadmap_ICEF2017.pdf

[12] Sandalow D et al., 2018, Direct Air Capture of Carbon Dioxide: ICEF Roadmap, Innovation for a Cool Earth Forum, https://www.icef-forum.org/pdf2018/roadmap/ICEF2018_DAC_Roadmap_20181210.pdf

five years ago. Technologies like direct air capture[13] and CO_2 mineralization, combined with turning CO_2 into fuels and building materials, can potentially become a new economic engine, with distributed manufacturing hubs in rural areas and cities alike. This vision is detailed by the National Academies - their recent report[14] calls for new funding and new authorities at the DOE.

All of these new imperatives are represented in the EFFECT Act. It would provide authorization to undertake this new and important work and proposes the appropriations levels necessary to have material economic effect. I see it as similar to the SunShot Initiative, which helped focus innovation in solar power and contributed substantively to achieving rapid and profound cost reductions in the US. The new authorizations of the EFFECT Act, matched by future appropriations, could achieve similar outcomes in a short number of years.

As essential as innovation investment is and as valuable as the EFFECT Act may prove, innovation alone will not bring these kinds of technologies to market. Many groups, including The Carbon Capture Coalition, the Global CCS Institute, Sec. Moniz at the Energy Futures Initiative, and my own colleagues at the Columbia Center on Global Energy Policy, stress that additional policies are needed to accelerate deployment and align markets for emissions reductions. These are a few important additional policy options the Committee may wish to consider:

- *Infrastructure*: Today, almost all CCUS is accomplished through the 5000 miles of shared CO_2 pipelines. Deployment of conventional CCUS will require thousands of miles more, mostly in the form of small regional networks that serve communities and regions while storing in local, high-quality geological storage sites.[15] Laws such as the USE IT Act, currently under consideration, could reduce risk and ambiguity for pipelines and make financing and operation easier. Additional incentives, such as block grants to states or regions, a competitive grant program managed by the Office of Fossil Energy, or something like an bespoke investment tax credit, could help greatly.
- *Capital Treatment Incentives*: CCUS projects of all kinds require 100's of millions to billions of dollars before the first ton is stored. Policies like private activity bonds, master limited

[13] Rhodium Group, 2019, Capturing Leadership: Policies for the US to advance direct-air capture technology, https://rhg.com/research/capturing-leadership-policies-for-the-us-to-advance-direct-air-capture-technology/
[14] Negative National Academies of Science, Engineering, and Medicine, 2018, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda, Washington, DC: The National Academies Press, https://doi.org/10.17226/25259.
[15] Great Plains Institute, 2017, 21st Century Energy Infrastructure: Policy recommendations for development of American CO2 pipeline networks, 27p,. https://www.betterenergy.org/wp-content/uploads/2018/02/GPI_Whitepaper_21st_Century_Infrastructure_CO2_Pipelines.pdf

partnership treatments, accelerated depreciation, investment tax credits, and economic activity zone designations would stimulate investment.[16]

- *Clean Energy Standards*: A well-designed national zero-emissions power standard or clean energy standard would allow CCUS and other clean energy options like advanced nuclear, geothermal, and CO_2 removal approaches to gain access to private financing. Recent legislative proposals[17] could provide this necessary support.
- *Public investment*: Direct public support of CCUS into heavy industry, in particular public-private partnerships for cement, steel, and petrochemicals, would help the US gain familiarity and speed with these approaches, while simultaneously stimulating construction, innovation, and regulatory certainty. This would quickly make the US the unambiguous leader of providing low-carbon products to market.
- *A price on carbon:* Our scholarship at CGEP has helped to assess the performance of various carbon pricing policies on national emissions. Recent work by one of the CGEP scholars (Dr. Noah Kaufman) has shown not only how a carbon tax might perform, but also how it could complement other greenhouse gas mitigation policies as well.[18]

In summary, I see the EFFECT Act as important legislation to help drive innovation. It would deliver valuable support to critical parties and actors building a clean energy future. I commend its authors for their insight and excellence in crafting the legislation. I also see it as one of many critical policy actions needed to meet the needs of the global climate and maintain economic security and strength. With that, I look forward to your comments and questions.

[16] Nagabhushan D & Thompson J, 2019, *Carbon Capture and Storage in the United States Power Sector: The Impact of 45Q Federal Tax Credits* (Boston: Clean Air Task Force), 14, https://www.catf.us/wp-content/uploads/2019/02/CATF_CCS_United_States_Power_Sector.pdf.
[17] Kaufman, N., 2019, "A Clean Energy Standard's Weaknesses May Be its Biggest Strengths, https://energypolicy.columbia.edu/sites/default/files/file-uploads/CES_CGEP_Commentary_Final.pdf
[18] Kaufman N, 2019, "Interactions Between a Federal Carbon Tax and other Climate Policies, https://energypolicy.columbia.edu/research/report/interactions-between-federal-carbon-tax-and-other-climate-policies

The CHAIRMAN. Thank you, Dr. Friedmann.
Mr. Goff, welcome.

STATEMENT OF ADAM GOFF, PRINCIPAL, 8 RIVERS CAPITAL, LLC

Mr. GOFF. Thank you, Chairman Murkowski, Ranking Member Manchin and members of the Committee for the opportunity to discuss carbon capture innovation and the EFFECT Act.

I will be discussing today a whole new method of carbon capture called the Allam Cycle, which was invented ten years ago by 8 Rivers, the innovation for and where I serve as Policy Director.

8 Rivers created the company NET Power to commercialize the natural gas Allam Cycle which has garnered over $150 million in investment between its four partners: 8 Rivers, Exelon, McDermott and Oxy Low Carbon Ventures.

NET Power built a successful 50-megawatt thermal plant and world class test facility in La Porte, Texas, that achieved combustor first fire in May 2018. The novel combustion and CO_2 turbine were supplied by our technology partner, Toshiba. This technology is a paradigm shift, because it has the potential to sell power at a lower price than conventional power plants, while releasing zero emissions. Today, multiple 300 megawatt-scale NET Power plants are in early stage development around the world.

Here's how it works. The Allam Cycle burns natural gas or coal in pure oxygen, rather than in air. This creates a high purity stream of CO_2 at 1150 degrees Celsius. This CO_2 is supercritical and is used to drive the turbine instead of using steam. That CO_2 is then ready to be sent to a pipeline at no additional cost.

CO_2 capture is inherent to the system, and selling CO_2 is actually a key source of our revenue. These multiple revenue streams are what give NET Power a cost advantage. And by using the supercritical CO_2, this cycle can reach the same efficiency as a conventional natural gas power plant all while achieving over 97 percent carbon capture and creating zero air pollutants.

The Allam Cycle also partners well with renewables ensuring the constant availability of low-cost, dispatchable clean energy. We believe it will allow the world to meet its climate targets at a cost that can be afforded by all people.

The Allam Cycle is a breakthrough technology, not just for the power sector, but also for the oil and gas, environmental and petrochemical sectors. It has the potential to lower the cost of electricity from fossil fuels while eliminating air emissions and capturing CO_2 for sequestration, enhanced oil recovery and other forms of carbon utilization. It will co-produce other valuable gases, nitrogen and argon which support America's manufacturing sector.

Each plank can also provide 150 megawatt-hours of energy storage, taking in excess renewable electricity and using it to create the pure oxygen this plan needs. That oxygen is then stored in tanks for later use when the sun sets or the wind slows.

While the Allam Cycle is a major breakthrough, it mostly utilizes proven components. Many of these, like advanced nickel alloys, were developed with federal research dollars. The Office of Fossil Energy has also directly supported Allam Cycle development, most recently through the Coal FIRST program.

NET Power also applauds the Committee for its introduction of the EFFECT Act. The legislation's focus on breakthrough carbon capture technologies, large-scale carbon sequestration and carbon utilization, is critical to the success of the entire carbon capture industry.

We appreciate that it spans the full R&D spectrum from research to pilots demonstration, all of which we've learned from our experience are necessary to commercial novel technologies.

Additionally, we thank Congress for its leadership in expanding the 45Q credit last year. These credits will accelerate the deployment of carbon capture technologies like NET Power, and they have made America the ideal location to demonstrate carbon capture projects.

Globally, NET Power envisions a robust market for this technology because of its low-cost profile. Countries like China and India could build coal and gas Allam Cycle plants purely for the economics with the follow-on benefit of reducing local air pollution and cutting global carbon emissions.

With innovative technologies like NET Power spreading beyond America's shores, we believe America—we believe clean energy can become affordable for the whole world.

Thank you.

[The prepared statement of Mr. Goff follows:]

Statement of Adam Goff
Principal
8 Rivers Capital, LLC

Senate Committee on Energy and Natural Resources
Hearing on Carbon Capture Technology and the EFFECT Act
May 16, 2019

Thank you Chairman Murkowski, Ranking Member Manchin, and members of the Committee. I appreciate the opportunity to discuss carbon capture innovation and the EFFECT Act. I will be discussing today a whole new method of carbon capture called the Allam Cycle, which 8 Rivers invented 10 years ago. 8 Rivers created the company NET Power to commercialize the natural gas Allam Cycle, and it has garnered over $150 million between its four investors: 8 Rivers, Exelon, McDermott, and Oxy Low Carbon Ventures. Toshiba has been our technology partner since 2011, supplying the two key components: the combustor and CO_2 turbine.

NET Power built a successful 50 MWth plant in La Porte Texas that achieved combustor first fire in May of 2018. This technology has the potential to sell power at a lower price than conventional power plants, while releasing zero emissions. Today, multiple 300 MW-scale NET Power plants are in early stage development around the world.

The Allam Cycle burns natural gas or coal in pure oxygen, rather than air. This creates a high purity stream of CO_2 at 300 Bar and 1150 Celsius. Instead of steam, this supercritical CO_2 is used to drive the turbine. That CO_2 can then be sent into pipeline at no additional cost. CO_2 capture is inherent to the system, and selling CO_2 is a key source of revenue. Multiple revenue streams give NET Power a cost advantage. And by using supercritical CO_2 as a working fluid, this cycle can reach the approximately the same efficiency as a conventional natural gas power plant while achieving over 97% carbon capture and creating zero air pollutants.

The Allam Cycle presents a breakthrough opportunity not just for the electricity sector, but also for the oil and gas, environmental, and petrochemicals sectors in the United States. The technology has the potential to lower the cost of electricity from fossil fuels, while virtually eliminating all air emissions and co-generating CO_2 for domestic Enhanced Oil Recovery (EOR), cement production and other forms of carbon utilization, as well as for underground sequestration. It will co-produce other valuable gases, Nitrogen and Argon, which support America's manufacturing sector.

By providing reliable, low-cost, and flexible power with virtually no carbon emissions, NET Power is an excellent complement to growing wind and solar energy portfolios around the world. Each NET Power plant can provide 150 MWH in energy storage services by taking in excess renewable electricity, using it to create pure oxygen, and storing the oxygen in tanks for later use when the sun sets or the wind slows.

This technology create a valuable export opportunity with large environmental upside. NET Power envisions a robust global market for this technology because of its low cost profile. Countries like China and India could build coal and gas Allam Cycle plants as a means of keeping their power costs low, with the added benefit of eliminating local air pollution and cutting global carbon emissions. With innovative technologies like NET Power, we believe clean energy will become affordable for the whole world.

While the Allam Cycle is a major technology breakthrough, it benefits from being a novel industrial process that mostly utilizes already-proven components, many of which were developed with federally supported R&D and operated at the required conditions of the Allam Cycle in other industries, such as the oil and gas industry. Both the turbine itself and combustor are novel and specific to the Allam cycle. Toshiba manufactured these components for the La Porte facility. The turbine relies on proven technologies from both the gas and steam turbine industries. The combustor, did require R&D by 8 Rivers and Toshiba, and it has since been proven at the commercial 50 MW scale at the NET Power plant in La Porte. So while 8 Rivers was the first company to design a direct-fired, oxy-combustion, supercritical CO_2 power cycle with the performance of the Allam Cycle, it was more quickly and effectively developed due to host of industry and federal government R&D for other purposes.

NET Power applauds the committee for its introduction of the EFFECT Act. The legislation's focus on breakthrough carbon capture technologies, large-scale carbon sequestration, and carbon utilization is critical to the long-term viability and success of the carbon capture industry. As a technology that will produce 809,000 tonnes of pure CO_2 per year at each plant, we are interested in all the potential uses of CO_2 and we view NET Power as a key enabling technology that provides the low cost carbon required for a thriving carbon utilization industry. Furthermore, we appreciate the wide scope of EFFECT act across the R&D spectrum, from research and large-scale pilots to demonstration project and to front-end engineering and design, all of which are necessary to commercialize novel technologies. America is well positioned to lead the world in carbon capture and storage technology, and this legislation will bolster America's technology leadership further.

Additionally we thank Congress for its leadership in expanding the 45Q tax credit for carbon capture as part of the February 2018 Budget Bill. These credits will accelerate the deployment of 300 MW-scale NET Power plants as well as a variety of other carbon capture technologies, spurring new infrastructure and new jobs while also reducing emissions.

8 Rivers' experience in commercializing this technology and others supports the view that the Federal Government has an important role in energy sector technology development, from R&D through to deployment. The R&D process is long, expensive, and highly uncertain; without government participation in the technology development process, it would be difficult for 8 Rivers to execute on its model of commercializing important energy innovations. Further, while private capital can and should play a major role in the demonstration and deployment of energy technologies, as it has with the Allam Cycle, development of first-of-their-kind commercial-scale facilities, and achieving initial market penetration thereafter, presents major challenges even for the most promising technologies, and the federal government is uniquely positioned to play an important role in overcoming those challenges.

Background on the Allam Cycle

8 Rivers is the inventor of the Allam Cycle, which is a high-pressure, direct-fired, oxy-combustion, supercritical carbon dioxide power cycle. The cycle takes natural gas or gasified coal and combusts it at high pressure and with pure oxygen (as opposed to air). This virtually eliminates the presence of nitrogen and generates a working fluid that is mostly carbon dioxide. This CO_2 working fluid is then used to drive a high-pressure gas turbine to produce power. The working fluid is then cooled in a heat exchanger so that water can be removed, and the remaining nearly-pure CO_2 working fluid is compressed, pumped, re-heated in the heat exchanger, and sent back into the combustor at high pressure and temperature. A portion of this high pressure CO_2 must be exported from the cycle; along with liquid water, it represents the only other emission from the process, and it can be removed already

at pipeline conditions for use in enhanced oil recovery, carbon sequestration, or as an industrial feedstock.

While the Allam Cycle is a major technology breakthrough, it benefits from being a novel industrial process that mostly utilizes already-proven components, many of which were developed with federally supported R&D and operated at the required conditions of the Allam Cycle in other industries, such as the oil and gas industry. A specific example of this federal government R&D is in materials development. At a critical, high- temperature portion of the Allam Cycle, it relies on an advanced nickel alloy that was developed, tested, and proven as a result of the U.S. Department of Energy (DOE) Fossil Energy Office's support of the Advanced Ultrasupercritical Steam Boiler and Turbine Consortium.[1] This program and material was originally developed to advance the steam boiler and turbine industry, but its results have also been key to the development of the Allam Cycle, where the materials enable us to push our temperatures higher and thereby reach higher efficiencies.

Similarly, the Offices of Nuclear Energy and EERE have previously funded work on "closed-loop" supercritical CO_2 power cycles. One such program, the SunShot Initiative, resulted in the development of corrosion and heat exchanger learnings that advanced the field for all technologies in the space, including the Allam Cycle.[2] Similar instances to these exist across a variety of technology fields supported by the U.S. Department of Energy, including gasification technologies, control systems, pump and compressor optimization, and others.

The Fossil Energy office has also directly participated in the Allam Cycle, assisting with the design of a syngas-fueled combustor for supercritical CO_2 power cycles, and supporting an R&D effort in North Dakota through the Energy and Environment Research Center (EERC). Most recently, Fossil Energy announced that the coal-based Allam Cycle was one of the grant recipients under the Coal FIRST Program. In addition, the DOE has expanded its work in the field of supercritical CO_2 power cycles with a crosscutting initiative aimed at developing R&D for nuclear, renewable, geothermal and fossil systems. 8 Rivers is hopeful that this effort advances the capabilities and expands the currently limited supplier-base for certain equipment in this important field.

Status of the Allam Cycle and NET Power

8 Rivers began developing the Allam Cycle in 2009, and it formed NET Power as a commercialization company for the natural gas-fueled version of the technology. NET Power has received over $150 million in investment from Exelon Corporation, a leading power company in the United States, McDermott, a global engineering and infrastructure firm; and Oxy Low Carbon Ventures, a subsidiary of Occidental Petroleum, the world's largest user of CO_2. Along with 8 Rivers, these four companies jointly own NET Power.

Separately, Toshiba has undertaken a major, multi-year effort to develop the turbine for NET Power. Together, the companies have built and are operating a 50MWth plant in La Porte, Texas.

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[1] NETL: https://www.netl.doe.gov/research/coal/crosscutting/high-performance-materials/Ultrasupercritical

[2] DOE Office of Energy Efficiency & Renewable Energy: https://energy.gov/eere/sunshot/sunshot-initiative

The design for this facility was dictated by a commercial-scale design for the Allam Cycle (300 MWe). The commercial plant was then scaled down as much as possible without fundamentally altering the design in order to minimize capital requirements while maximizing both risk reduction and scalability back to the commercial size. The result is a plant that is 10X smaller than a commercial-scale plant, but is a full Allam Cycle supercritical carbon dioxide power system (with the exception that oxygen will be purchased from a pipeline as opposed to constructing a dedicated air separation unit) that will sell power into the Texas market. The 50 MW combustor built by Toshiba and demonstrated in La Porte is at full commercial scale- there will be 12 of this same 50 MW combustor for a larger 300 MWe facility.

The plant is the first facility of its kind in the world and has provided a major leap forward in the field of direct-fired supercritical CO2 power cycles and carbon capture. This facility is providing sufficient confidence in the technology to execute on the 300MW commercial-scale facilities that NET Power is presently developing. NET Power announced successful first fire of the combustor, the key technical milestone for the facility, in May of 2018, and the facility is continuing operational testing.

Impact and Benefits of the Allam Cycle

The Allam Cycle offers a number of major benefits to the power sector, the environment, and the oil and gas industry.

For the power sector, the technology is targeting a cost of electricity that competes with current best-in-class fossil technologies that do not eliminate carbon emissions, without ascribing any economic value to the Allam Cycle's usable byproducts, such as pipeline quality CO_2, nitrogen, argon and oxygen. When reasonable values are assumed from selling these byproducts, the Allam Cycle is actually capable of dramatically undercutting the cost of electricity from these incumbent technologies. This is because the cycle is highly efficient – on par with today's NGCC plants without CCS and much higher than the best-available coal plants without CCS – and has low capital costs – targeting comparable costs to NGCC for natural gas and much lower costs than IGCC for coal.

For the environment, the Allam Cycle provides vastly superior environmental performance when compared to today's best fossil fuel technologies. Because the cycle utilizes oxy-combustion, NOx production is virtually eliminated; with the coal system, SOx, mercury, and particulate emissions are also virtually eliminated. Additionally, the cycle offers the ability to have greater than 97% carbon capture with virtually no economic penalty to the plant because the cycle is designed to derive its efficiency from using a nearly pure, high-pressure carbon dioxide working fluid to produce power; it does not require a separate, bolt-on carbon capture system.

By providing reliable, low-cost, and flexible power that has virtually no carbon emissions, the Allam Cycle is an excellent complement to growing wind and solar energy portfolios around the world. The IPCC Fifth Assessment modeling concluded that trying to reach carbon emissions reduction targets without CCS would result in the highest costs and least number of successful reduction scenarios.[3] The Allam Cycle is ideally suited to fit into the overall generation portfolio in a way that supports renewable technologies on the grid and enables the deepest possible emissions reductions to be achieved without resulting in increased costs to, and decreased reliability of, the electricity system. Each NET Power plant

[3] IPCC 5th Assessment Synthesis Report, *Summary for Policy Makers*, pg. 25: https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf

can provide 150 MWH (30 MW / 5 Hours) in energy storage services, by taking in excess renewable electricity, using it to create pure oxygen, and storing the oxygen in tanks for later use.

For the oil and gas and petrochemicals industry, the Allam Cycle can drive down costs, expand development, and improve environmental performance. The Allam Cycle uses a conventional cryogenic air separation unit (ASU) to produce oxygen for combustion. The ASU will also produce nitrogen, argon, and excess oxygen (at times when the power plant isn't utilizing the oxygen), all of which are important industrial feedstocks and salable byproducts that can be affordably produced by the plant.

The most immediate impact the Allam Cycle will have on the oil and gas industry is its ability to produce low-cost, pipeline-ready carbon dioxide for CO2-EOR. The ability to economically recover oil via CO2-EOR is primarily dependent on the price of oil and the price of the CO2 needed to produce that oil. Traditional, add-on carbon capture technologies produce CO2 at a cost of approximately $30-$70/ton.[4] With recovery rates in the range of 1.5-3 barrels per ton of CO2 injected, these technologies require very robust oil prices in order to be economically viable.[5] By producing EOR-ready CO2 for virtually no cost, the Allam Cycle enables CO2-EOR to be one of the lowest-cost methods of oil recovery available, making it resilient to drops in oil prices, and greatly expanding the economically recoverable supply here in the United States. A 2013 Advanced Resources International (ARI) report estimates that 100 billion barrels are economically recoverable using "next generation" technologies (assuming oil at $85/barrel and CO2 at $40/ton). In that same report, ARI also estimates that new, un-tapped "Residual Oil Zones" hold an additional 140 billion barrels of oil, of which 27 billion barrels are economically recoverable.[6] Further, the Allam Cycle's ability to provide low-to-no-cost CO2 would increase the amount of oil believed to be economically recoverable in each of these projections.

Importantly, because the Allam Cycle's potential to expand domestic oil production from CO2-EOR is so significant, so is its ability to permanently and safely store vast quantities of CO2 generated by the power sector through EOR.[7] In order to produce the 100 billion barrels of oil that ARI estimates are economically recoverable with next generation technologies, approximately 33 billion tons of CO2 will be required. This equates to the 35-year CO2 output of over 250 gigawatts natural gas power plants.[8]

NET Power is also looking to carbon utilization, from plastics to cement, and carbon sequestration as key offtakes for CO_2, which greatly expand the domestic map of potential locations for NET Power facilities. The DOE has estimated the total storage capacity in the United States ranges between 2.6 trillion and 22 trillion tons of CO_2.[9] The ideal use of CO_2 for each plant is likely to vary highly by region and by specific plant location.

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[4] US DOE, *Carbon Capture, Utilization, and Storage: Climate Change, Economic Competitiveness, and Energy Security*, pg. 5: https://energy.gov/sites/prod/files/2016/09/f33/DOE%20-%20Carbon%20Capture%20Utilization%20and%20Storage_2016-09-07.pdf

[5] IEA, *Storing CO2 through Enhanced Oil Recovery*, pg. 12: https://www.iea.org/publications/insights/insightpublications/Storing_CO2_through_Enhanced_Oil_Recovery.pdf

[6] ARI, *CO2 Utilization from "Next Generation" CO2 Enhanced Oil Recovery*, pg. 6855: http://ac.els-cdn.com/S1876610213008618/1-s2.0-S1876610213008618-main.pdf?_tid=1d87e6fa-2e26-11e7-8a95-00000aab0f6c&acdnat=1493612869_cba2651ceafcf29c6ee51cfae089f63c

[7] Literature shows that only about 0.3% of the CO2 sued for injection is lost to the atmosphere; IEA, *Storing CO2 through Enhanced Oil Recovery*, pg. 12.

[8] ARI, *CO2 Utilization from "Next Generation" CO2 Enhanced Oil Recovery.*

[9] Carbon Capture and Sequestration (CCS) in the United States, CRS Report. https://fas.org/sgp/crs/misc/R44902.pdf

The Allam Cycle can also impact natural gas utilization in the United States and abroad. By providing highly cost- competitive and clean power generation from natural gas, the Allam Cycle can increase natural gas export opportunities for the United States, particularly to areas that are beginning to restrict and tax carbon emissions, and allow for the natural gas we export to be burned without emitting CO_2. The Allam Cycle also has the ability to efficiently and cleanly burn unprocessed natural gas. This ability to burn these gases lowers the cost of natural gas, as certain clean-up steps are eliminated from gas processing, and enables natural gas that would otherwise be unused or flared to be utilized, decreasing emissions from the oil and gas sector.

Concluding Perspectives on the Role of the Federal Government in Energy Technology R&D

The development of the Allam Cycle and NET Power demonstrates that R&D partnerships with the federal government are critical to the advancement of energy innovations, even if it is ultimately applied in unexpected settings. In particular, entrepreneurial firms such as 8 Rivers would be unable or unlikely to independently take on the timeframe, cost, and uncertainty of developing something as essential as a new alloy in order to deploy a brand new energy system; DOE collaboration is critical in these areas and has had a significant impact, even if it is not always immediately apparent.

A critical theme to 8 Rivers' process is that innovation is highly unpredictable, and neither the private sector nor the Federal Government can always be certain where it will lead. 8 Rivers looks to be problem-focused, rather than wed to a technology, and the company must remain flexible and willing to pivot a technology when necessary. Similarly, Federal R&D programs should also be highly goal-oriented across the technology portfolio, not just within each technology silo, and programs should not be so prescriptive as to prevent them from pivoting in new directions when necessary and within reason. Encouraging this flexibility would not only help DOE efforts to move more quickly, but it would also help the private sector engage in those efforts more easily, as they can remain highly relevant to the direction in which the private sector is moving.

An example related to the Allam Cycle where added flexibility for the DOE would be beneficial is to have a greater ability to participate in both coal and natural gas power technologies within the Office of Fossil Energy. The EFFECT Act proposes this exact flexibility. 8 Rivers began by working on the Allam Cycle for coal, but it become quickly apparent that the coal development pathway must first proceed through natural gas; this was the lowest-cost, least-risky, and most-impactful approach, because the most important development step for the coal-fueled Allam Cycle is NET Power's natural gas demonstration program. Similar crosscutting opportunities exist across the Department of Energy Fossil Energy technology portfolio, and the flexibility to also collaborate on natural gas technologies can also enable technology to advance more quickly and with less risk for both fuel sources.

Finally, 8 Rivers' experience is that Federal Government partnerships remain critical to the technology development process from basic R&D through to deployment of the first-of-its-kind commercial-scale plant, and even into additional early commercial plants thereafter through incentives like 45Q. A first-of-its-kind commercial-scale facility will need to operate commercially in the market in order to be developed, and yet it will be a more expensive project than the second facility of its kind will be. There are number of challenges that are unique to being a first-of-a-kind. Because they are not yet mature technologies with full customer order books, they will not receive the benefit of a supply chain that has maximized its efficiencies and become fully competitive.

So, while a technology might easily project to outcompete incumbent technologies, a first plant will still be more expensive, making it an enormous challenge for it to be successful in the market. 8 Rivers views programs that partner with the private sector through grants and tax credits that assist the private sector in developing and financing these first-of-a-kind projects as critical to ensuring that promising technologies have a chance to be initially deployed into the market.

The cost challenges seen with first-of-a-kind facilities do not completely dissipate by the second plant, though. They reduce over time, and as the technology becomes more widespread, in the case of carbon capture, they also include the need to further expand infrastructure such as CO2 pipelines. Tax credits like 45Q are essential to ensuring technologies like NET Power can be widely and quickly deployed. This will maximize their ability to transform the power sector with lower cost electricity while permanently storing its CO_2, whether by making cement or plastics, injecting CO_2 for enhanced oil recovery, or sequestering it in saline formations.

Thank you for the opportunity to testify today, and I welcome any questions you have.

The CHAIRMAN. Mr. Goff, thank you very much.
Mr. Harju.

STATEMENT OF JOHN HARJU, VICE PRESIDENT FOR STRATEGIC PARTNERSHIPS, UNIVERSITY OF NORTH DAKOTA ENERGY & ENVIRONMENTAL RESEARCH CENTER

Mr. HARJU. Good morning, Chairman Murkowski, Ranking Member Manchin and members of the Committee, and thanks to Senator Hoeven, now gone, for the kind introduction. I'm happy to provide a brief commentary today regarding what I call EERC, which stands for Energy & Environmental Research Center, a business unit of the University of North Dakota, and we're focused on providing practical solutions to the world's vexing energy and environmental challenges.

We were initially founded in 1951 under the U.S. Bureau of Mines. Later we became one of the Department of Energy's five energy technology centers and since 1983 have been part of the University of North Dakota.

Our mission has evolved considerably since that time, initially focused exclusively on coal utilization and at this point in time, focused on all forms of energy and the intended environmental challenges associated with their development and utilization.

In the arena of CCUS, EERC has had the privilege of serving a very, very large number of partners across the entire CCUS value chain. These projects have included everything from broad reconnaissance-level assessments of storage opportunities to detailed assessments of prospective storage reservoirs and field validation of ongoing commercial scale CCUS projects, from cursory desktop evaluations of numerous capture technologies to pilot tests and ongoing field campaigns of their performance for full-scale deployment, also from paper studies of new-generation platforms such as the Allam Cycle to pilot testing and demonstration-scale field evaluations. So again, across the entire broad value chain of CCUS. These projects have benefited from ongoing, robust financial support via the Department of Energy's Fossil Energy Program.

Way back in 2003, the Department launched a solicitation to establish a series of Regional Carbon Sequestration Partnerships and Senator Hoeven mentioned that earlier as well. But the focus at that point in time was to develop a regional inventory of sources and sinks. EERC's partnership there is called the PCOR partnership. And one of those first eye-opening things for a simple fellow like me was our region's emissions are inextricably linked to our economic activity. So whether that's the mining and manufacturing and industrial centers around the Great Lakes or in the Mississippi River Valley or the agribusinesses of Iowa, Minnesota, Nebraska or the Dakotas, or the oil and gas and coal-producing regions of the Northern Great Plains, each of these areas has an economic engine and each of those economic engines represent the primary emission of CO_2.

A key partner offered way back then that he doesn't see a carbon constrained world but rather a carbon managed world, and with that as a backdrop we set out to develop what we found to be economically viable, carbon management activities. Today, our part-

nership has growing interest with more than 120 engaged, strategic partners.

So in subsequent phases of work we led a series of four discrete field experiments, each of those inherently tied to one of those significant engines and opportunities. Concurrent efforts of my team in conjunction with numerous additional stakeholders and under the leadership of then-Governor Hoeven, our state established comprehensive geologic storage rules for carbon dioxide and later became the first and still the only state-granted primacy under the EPA's Class VI storage program.

So the most recent phase of our effort has been focused on full commercial-scale validation of EOR-related storage at Denbury Resources' Bell Creek Field in southeastern Montana. CO_2 is sourced from natural gas processing facilities in Wyoming, brought to the field and used in EOR.

The field currently produces more than 7,000 barrels a day, that's up from a few hundred barrels a day at the time of implementation, and at full fruition the project will produce more than 40 million barrels of oil and permanently store more than 15 million tons of CO_2. At this point more than six million tons of CO_2 have been stored at that location.

Gas processing facilities, such as that which are sourced for Bell Creek, really represent "low-hanging fruit" in terms of available and readily capturable CO_2, but we don't see substantial opportunity to expand that because of either low concentrations of CO_2 in that gas processing feedstock or because they're already being captured.

Ethanol facilities also represent a substantial opportunity and we're fortunate enough to be working with Red Trail Ethanol in North Dakota on a facility, also focused on geologic storage of CO_2.

Senator Hoeven mentioned Project Tundra, another key effort in our area that we've been fortunate enough to be engaged in. That project, led by Minnkota Power Cooperative, is working to deploy a post-combustion capture system at Minnkota's Milton R. Young facility. That CO_2 captured would be used and stored in regional oil fields for EOR and also that location is the host of one of the CarbonSAFE efforts that Mr. Winberg and Dr. Friedmann had mentioned.

We see CarbonSAFE as a key compliment to the regional partnerships program. CarbonSAFE being one where we validate specific geologic storage sites of a minimum size and nature, but we see the regional partnerships as helping us develop and build out these compelling business cases that, I think, allow CO_2 storage to become a substantial part of our economic framework.

None of this work would have been possible without the foresight of this key Committee, your counterparts in the Appropriations Committee and the Department of Energy. Senate bill 1201 continues this critical recognition and support of the programs that drive our innovation.

I'm particularly pleased with the bill's recognition of the regional carbon sequestration partnerships and CarbonSAFE efforts. We're currently preparing a key proposal to DOE that would expand our region to include the key energy State of Alaska and to broaden and complete our engagement with the State of Wyoming.

Thank you very much for your time, and I look forward to your questions.

[The prepared statement of Mr. Harju follows:]

Testimony of John Harju, Vice President for Strategic Partnerships
University of North Dakota Energy & Environmental Research Center
Before the Senate Committee on Energy and Natural Resources
May 16, 2019

Good morning, Chairman Murkowski, Ranking Member Manchin, and members of the committee. My name is John Harju, and I am the Vice President for Strategic Partnerships at the University of North Dakota's Energy & Environmental Research Center (EERC). Thank you for the invitation to provide brief commentary today regarding the EERC's carbon capture, utilization, and storage (CCUS) activities that directly complement the provisions espoused in Senate Bill 1201, the Enhancing Fossil Fuel Energy Carbon Technology Act of 2019.

The EERC is a business unit of the University of North Dakota focused on practical solutions to our world's vexing energy and environmental challenges. The EERC was initially founded in 1951 as the Robertson Lignite Research Laboratory, under the U.S. Bureau of Mines. With the creation of the U.S. Department of Energy (DOE) in 1977, we became one of the nation's five energy technology centers and have been a part of the University since 1983. The EERC's mission has evolved considerably since that time, from a mission focused exclusively on the utilization of the low-rank coals that predominate our nation's resources west of the Mississippi River to a mission that focuses on all fossil fuels, as well as renewable and alternative fuels, and on attendant environmental challenges associated with their development and utilization.

In the arena of CCUS, the EERC has had the privilege of serving not only DOE, but also more than 100 nonfederal partners across the entire CCUS value chain. These projects have included everything from broad reconnaissance-level assessments of storage opportunities to detailed assessments of prospective storage reservoirs and field validation of ongoing CCUS projects; from cursory desktop evaluations of numerous capture technologies to pilot tests of many emerging capture techniques and ongoing field campaigns evaluating their performance for full-scale implementation; and from paper studies of new-generation platforms to pilot testing and demonstration-scale field evaluations. These projects have benefited from ongoing, robust financial support via DOE's Fossil Energy Program. Specifically, that support has spanned DOE's Advanced Energy Technology Program, Carbon Capture Program, Carbon Storage Program, and Storage Infrastructure Program.

In 2003, DOE released a solicitation for the establishment of a series of Regional Carbon Sequestration Partnerships to develop an inventory of our nation's major stationary CO_2 emission sources, as well as the attendant regional storage reservoirs, or "sinks." My team at the EERC was fortunate enough to be selected as one of the original seven partnerships in a region that ultimately spanned all or part of nine U.S. states and four Canadian provinces, which we refer to as the Plains CO_2 Reduction Partnership, or PCOR Partnership. What became apparent over the course of those earliest activities was that while our region has astounding potential for geologic CO_2 storage, our region's emissions are inextricably linked to our economic bases—from the mining, manufacturing, and industrial centers around the Great

Lakes and Mississippi River Valley; to the agribusinesses of Iowa, Minnesota, Nebraska, and the Dakotas; to the oil-, gas-, and coal-producing regions of North Dakota, Montana, Wyoming, and the Canadian provinces. Each of these distinct regions has an economic engine, and each of those economic engines represent the primary emission of CO_2. What also became apparent was that without the engagement of key stakeholders from within each of those economic bases, there was likely little opportunity to forge meaningful field evaluations of CCUS technology. A key partner offered that he does not see a carbon-constrained world, but rather a carbon-managed world. With that as a backdrop, we set out to find and develop those economically motivated carbon management opportunities. Today, the PCOR Partnership's membership reflects both ongoing and growing interest, with more than 120 strategic partners throughout our region.

A subsequent phase of effort spanned the years 2005–2008, and in that time frame the EERC was fortunate to have the opportunity to lead four discrete small-scale field experiments. The first was a terrestrial, or "indirect sequestration," effort in partnership with Ducks Unlimited and Ducks Unlimited Canada, wherein the carbon uptake of restored wetlands was validated and helped facilitate the monetization of carbon credits associated with wetland restoration. A second effort, in partnership with Apache Canada, validated the use of a CO_2–H_2S mixture from a nearby gas-processing facility as a working fluid for enhanced oil recovery (EOR) and attendant storage in Alberta's Zama Field. A third project evaluated the injection of CO_2 into North Dakota's most prolific conventional oil reservoir for EOR/CCUS. Finally, the fourth effort evaluated the injection of CO_2 into an unminable lignite seam to evaluate the potential for enhanced coalbed methane production and attendant CO_2 storage. As mentioned previously, each of these field experiments was inherently tied to a regionally significant economic engine and opportunity. And each of these field experiments substantially informed and guided our activities for the ensuing decade. Concurrent efforts of my team, in conjunction with numerous additional stakeholders led to North Dakota's development of comprehensive geologic storage rules for CO_2 that ultimately led to North Dakota being granted primacy for the U.S. Environmental Protection Agency's (EPA's) Class VI Program. As of today, North Dakota remains the only state with this primacy.

The most recent phase of our PCOR Partnership effort has focused on the full commercial-scale validation of EOR-related CO_2 storage at Denbury Resources' Bell Creek oil field in southeastern Montana. CO_2 is sourced from natural gas-processing facilities in Wyoming and transported via pipeline to the field. As of June 2018, the Bell Creek Field, had stored more than 5.9 million tons of CO_2, and an additional 5.6 million barrels of oil had been produced. At full fruition, the project is expected to produce up to 40 million barrels of oil and permanently store more than 15 million tons of CO_2.

Gas-processing facilities have represented "low-hanging fruit" in terms of regionally available CO_2, and at this point in time have minimal opportunity for expanded capture and use or storage in our region. Other regional low-hanging fruit is in the form of CO_2 from ethanol facilities, a by-product of the fermentation of corn. While only modest volumes of CO_2 are produced at each individual ethanol facility, that CO_2 is very pure and requires little processing

for reuse or geologic storage. The EERC has been fortunate to work closely with Red Trail Energy, a North Dakota-based ethanol producer, and we are proceeding toward field implementation of geologic storage of CO_2 proximal to Red Trail's facility. Aggregation of numerous ethanol facilities in other parts of the region also represents an opportunity for much larger storage or utilization projects.

Coal-fired power facilities represent the largest point sources of CO_2 emissions in our region and also represent some of the most difficult CO_2 to capture because of the dilute nature of CO_2 in the postcombustion flue gas and the complexity of other constituents in that flue gas stream. Our work via our Partnership for CO_2 Capture Program and subsequent efforts for technology developers, DOE, and utilities interested in the potential deployment of capture technologies have familiarized my team with most of the emerging CO_2 capture technologies that might be deployed on coal-fired facilities in the near future. In fact, my team has either performed developmental work or conducted pilot evaluations on most of these technologies. With that as a backdrop, the EERC began working in earnest with the development team for Project Tundra, led by Minnkota Power Cooperative. Project Tundra is currently working on a pre-FEED (front-end engineering and design) effort that will develop preliminary cost estimates for the deployment of a postcombustion capture system at the Minnkota-operated Milton R. Young facility near Center, North Dakota. The captured CO_2 will be used in regional oil fields for EOR and/or stored in a proximal saline formation. Project Tundra is an integrated CO_2 CCUS project that represents the next unit of scale-up from NRG's Petra Nova project, which you will also be hearing about today. Project Tundra also represents an important regional anchor for a DOE-sponsored CarbonSAFE effort that is evaluating the potential for the geologic storage of 50-plus million tons of CO_2 near the Milton R. Young plant.

The CarbonSAFE Program represents a key thrust of DOE's portfolio, namely the validation of large-scale geologic storage in saline formations. My team sees CarbonSAFE as complementary to the RCSP Program. While the RCSP Program focuses on developing compelling business cases for carbon utilization and management, the CarbonSAFE Program focuses on developing specific geologic storage sites of a minimum size and nature. In addition to leading the North Dakota CarbonSAFE effort, the EERC team has had the opportunity to also serve as a partner in additional CarbonSAFE investigations in Nebraska and Wyoming.

Finally, my team has had the opportunity to work on several elements of DOE's advanced technology portfolio, wherein next-generation energy production platforms are being developed that promise to revolutionize the way we generate energy and embrace the concomitant desire to manage CO_2. The most recent example of the EERC's work therein is our effort with 8 Rivers Capital, which is focused on developing a coal-fueled platform for the company's Allam Cycle, which you have also heard about today from Adam Goff.

None of this outstanding research and development work performed by the EERC would have been possible without the foresight of this key committee, your counterparts on the Appropriations Committee, and DOE. Senate Bill 1201 continues this critical recognition and support of the programs that drive our innovation. I am particularly pleased with the Bill's

recognition of the Regional Carbon Sequestration Partnerships. We are currently preparing a key proposal to DOE that would expand our region to include the key energy state of Alaska and to broaden our Wyoming engagement from just the Powder River Basin to include the entire state. With your direction and leadership, I believe that we are poised to continue our nation's progress toward broad, economically viable carbon management.

Thank you, again, Chairman Murkowski, Ranking Member Manchin, and members of the committee for your invitation to provide these remarks. I would be happy to answer any questions you might have regarding my testimony and my views on carbon management.

The CHAIRMAN. Thank you, Mr. Harju, we appreciate that.
Mr. Jackson, welcome.

STATEMENT OF RICHARD JACKSON, PRESIDENT, LOW CARBON VENTURES, OCCIDENTAL PETROLEUM

Mr. JACKSON. Chairman Murkowski, Ranking Member Manchin, members and staff of the Senate Environment and Natural Resources Committee, thank you for the opportunity to testify.

I appreciate your leadership on carbon capture and the EFFECT Act which Occidental is proud to support.

My name is Richard Jackson, and I work as President at Occidental's Low Carbon Ventures. Occidental is one of the largest independent oil and gas companies in the United States. We have spent the last few years working with internal and external stakeholders to discuss climate change and solutions. I look forward to discussing those with you today.

Low Carbon Ventures was formed in 2018 to enhance our business and reduce atmospheric greenhouse gas. Today our management is exploring an aspiration of becoming carbon neutral, accounting not only for our operational emissions but also for the emissions related to the use of our products. We seek to do this while continuing to grow our business.

The significant driver is carbon capture and use, with the near-term ability to produce a carbon neutral barrel of oil. The technology we use will also help advance other commercial low carbon products and business opportunities.

While we appreciate there are many different low carbon strategies for energy companies, at Occidental we are in a unique position as the world's largest consumer of CO_2 which we have used for over 40 years in enhanced oil recovery or EOR operations. We sequester over one billion cubic feet of CO_2 per day which is the emissions equivalent of four million passenger vehicles. Utilizing more man-made CO_2 will allow us to grow this business while sequestering significantly more.

As we look forward to meeting a lower carbon energy demand, our capability presents great potential. In fact, the International Energy Agency confirms that a barrel of oil produced using man-made CO_2 has a significantly reduced carbon footprint compared to a conventional barrel.

While we estimate we can, at Oxy we estimate we can reduce this further enabling us to produce a carbon neutral and even carbon negative barrel of oil. In short, we are increasing today's production, tomorrow's reserves and significantly decreasing our collective carbon impact.

Currently CO_2 EOR offers the most favorable economic approach to carbon capture. However, we believe the future will hold many other commercial uses for CO_2, everything from making synthetic, low carbon fuels, to low carbon materials like cement and plastics. EOR can pave the way in the near-term, not only for carbon capture but also for critical CO_2 pipeline infrastructure, that can help drive this innovation and commercializing of new products.

Occidental is investing and partnering to advance these innovative uses of CO_2. We believe these business-driven solutions will

have a meaningful and profound impact on reducing CO_2 emissions, not only in the United States but across the globe.

While we believe that carbon capture, utilization, and sequestration is a critical technology to meet many of our nation's priorities, we also believe it should complement other low carbon solutions. At Oxy we are focused on three: reducing the emissions from our own operational activities; energy efficiency; and, of course, carbon capture of use, both from industrial sources and also directly from the air.

Oxy Low Carbon Ventures have found significant value in working with non-traditional allies to advance these goals and we have made three major announcements in the last year: With White Energy, a biofuels producer in Texas and Kansas, we're exploring options for capturing man-made CO_2 from their ethanol facilities; Occidental invested with NET Power which joins us today which develops zero emission natural gas-powered generation; we also invested in British Columbia-based Carbon Engineering which developed a technology that pulls CO_2 from the atmosphere.

Occidental is proud to be involved in key carbon reduction coalitions, including the Oil and Gas Climate Initiative and the Carbon Capture Coalition. Partnerships like these would not have been possible for us without the work of the Senate to expand and extend 45Q and the tax credit in 2018 making investment in carbon capture possible.

As our CEO, Vicki Hollub, has said, partnerships with a variety of stakeholders is the most efficient and perhaps the only pathway to solving climate change risk. To that end, we ask Congressional leadership to help advance commercialization through large-scale CO_2 transportation networks. Regional and then national large-scale CO_2 pipeline networks act as the foundation for a CO_2 economy, moving CO_2 from emissions to commercial uses.

We look forward to working with you to incentivize the build-out of a robust national CO_2 transportation network.

Thank you for the opportunity to speak with you today about an issue that our CEOs, our employees and I are very passionate about. I look forward to helping answer any questions that you may have.

[The prepared statement of Mr. Jackson follows:]

Testimony of Richard Jackson
President, Low Carbon Ventures
Occidental Petroleum
Committee on Energy and Natural Resources
May 16, 2019

Chairman Murkowski, Ranking Member Manchin, and Members and staff of the Senate Environment and Natural Resources Committee, thank you for the opportunity to testify. I'd also like to thank you for your leadership on carbon capture and the EFFECT Act - a piece of legislation that Occidental is proud to support.

My name is Richard Jackson, and I work as President of Occidental's newly formed subsidiary, Low Carbon Ventures. Occidental is one of the largest independent oil and gas companies in the United States, by market capitalization, and is headquartered in Houston, TX. Our domestic operations are in the Permian Basin of West Texas and Southeast New Mexico, and our core international operations are in Oman, UAE and Colombia. In 2018, we produced more than 650,000 barrels of oil equivalent per day, with a global workforce of nearly 38,000 employees and contractors.

Low Carbon Ventures was formed in 2018 to enhance our business and reduce atmospheric greenhouse gas. We are proving that we can decrease CO_2 emissions while making smart business decisions. In fact, Occidental management is exploring an aspiration of becoming carbon neutral, accounting for not only our operational emissions but also for the emissions related to the use of our products. We seek to do this while continuing to grow our business. The significant driver will be carbon capture and use, with the near-term ability to produce a carbon neutral barrel of oil. The technology we use will also helping create many other commercial low carbon products and business opportunities in the future.

We appreciate that there are many different low carbon strategies for an energy company. Occidental truly is an all of the above energy company. We purchase natural gas and coal-fired power for electricity. We partner with ethanol producers. Some of our chemical facilities have cogeneration technology that allow us to burn the hydrogen byproduct from our chemical operations to make zero-carbon power. And we are expanding our use of solar power. We are currently installing a 16MW solar facility at an oilfield in Odessa, Texas, which will reduce our emissions and help us with energy efficiency. In Oman, we are partnering with GlassPoint to build one of the world's largest solar arrays to generate steam that will be used to produce oil with a lower carbon intensity.

At Occidental, we are in a unique position as the world's largest consumer of CO_2, which we used to support a successful, mature business with tremendous growth potential. For context, we inject over 2.6 billion cubic feet of CO_2 every day or– 50 MMT per year. Of that 50 MMT,

about 18 MMT is permanently sequestered, while the balance is safely recycled for reinjection until permanently stored underground. Each year, we sequester the carbon equivalent of the emissions from 4 million passenger vehicles. Utilizing more man-made CO_2 will allow us to grow this business while sequestering significantly more CO_2.

We have been injecting, transporting, and separating CO_2 for use in enhanced oil recovery (EOR) for over 40 years. Using EOR, we are able to get 10%-25% more oil out of our reservoirs – oil that otherwise would not be recovered. And because we operate closed-loop systems, virtually all of the CO_2 we inject is permanently and safely sequestered in the geology of the reservoir.

As we look forward to meeting a lower carbon energy demand, our capability presents great potential. The oil we can produce using captured, man-made CO_2 has a much lower total carbon footprint than a conventional barrel of oil. In fact, the International Energy Agency recognizes that a barrel of oil produced using man-made CO_2 has a significantly reduced carbon footprint compared to a conventional barrel of oil. At Occidental, we estimate we can reduce this further to enable us to produce a carbon neutral and even carbon negative barrel of oil. In short, we are increasing today's production, tomorrow's reserves, and significantly decreasing our collective carbon impact. We think this is an example of American innovation at its best.

Currently, CO_2 EOR offers the most favorable economic approach to carbon capture. We purchase the CO_2 as a process feedstock much like a farmer uses fertilizer to increase his crop yield. However, we believe the future will hold many other commercial uses for CO_2 – everything from making synthetic low-carbon fuels to low carbon materials like cement and plastics. EOR can pave the way in the near term not only for carbon capture, but also for critical CO_2 pipeline infrastructure that can drive innovation and commercialization of these products. Occidental is investing in and partnering with research organizations and start-ups to advance these innovative uses for CO_2. They are setting a foundation for a new economy based on utilizing CO_2 instead of emitting it. We believe these business-driven solutions will have a meaningful and profound impact on reducing CO_2 emissions not only in the United States but across the globe.

While we believe that carbon capture, utilization and sequestration is a critical technology to meet many of our nation's priorities, we also believe that it should complement other critical low carbon solutions. Occidental is focused in three key areas for emissions reductions: reducing the emissions from our own operational activities, energy efficiency and carbon capture and use – both from industrial sources and directly from the air. We have found significant value in working with non-traditional allies to advance these goals.

Last year, Occidental announced a feasibility study with White Energy, a biofuels producer in Texas and Kansas. This study would outline options for capturing CO_2 from White Energy's ethanol facilities in the panhandle of Texas and transport that anthropogenic (manmade) CO_2 to the Permian Basin for EOR. The project could potentially sequester approximately 1 million

tons of CO_2 per year. Our partnership is an important first step in cross-industry collaboration to make carbon capture economic, practicable and scalable.

In November, Occidental joined Exelon, McDermitt, and 8Rivers to partner with NETPower, a zero emissions natural gas power generation facility. NETPower's power generation technology with built-in carbon capture complements Occidental's leadership in CO_2 utilization and sequestration, making us ideal partners to tackle carbon emissions worldwide.

Most recently, Occidental announced an investment in British Columbia-based Carbon Engineering, which is a company invested in Direct Air Capture. This technology pulls CO_2 directly from the atmosphere, and uses a chemical process to separate the CO_2 from other gases. That CO_2 can then be used for any number of purposes, including but not limited to, EOR. The direct air capture plants are location independent and can be co-located with the commercial use business, eliminating the need for additional transportation or pipeline costs.

Many of these partnerships would not have been possible without the work of the Senate to expand and extend the 45Q tax credit in 2018. 45Q makes the investment in carbon capture possible, enabling more efficient and economic technology. Occidental sees the opportunity here to reach more industrial facilities and capture more CO_2 for EOR now and feedstock for plastics, cement fuels and other products in the future.

Occidental is also involved in key carbon reduction coalitions and believes this to be critical. Two I will highlight are the Oil and Gas Climate Initiative and the Carbon Capture Coalition. OGCI, is comprised of 13 international oil and gas companies that represent 25% of the world's production, who have come together with a joint investment of more than $1 billion to be used over the next 10 years to advance low-carbon solutions for the energy, industrial and transportation value chains. The Carbon Capture Coalition is an impressive organization with over 60 members. Representatives from labor, environmental NGOs, oil and gas, coal and others meet regularly to discuss ways in which we can advance the deployment of carbon capture. The breadth of this group demonstrates that carbon capture is a solution supported by many as a proven technology to reduce CO_2 emissions. As our CEO, Vicki Hollub, has said many times, partnerships with a variety of stakeholders, regulators and legislators is the most efficient and perhaps the only pathway to solving climate change risk. We are proud of these relationships and welcome the opportunity to work with these and other stakeholders.

At Occidental, we continue to seek ways to decrease emissions and invest in low-carbon energy sources. However, we do believe there's a role for Congressional leadership when it comes to carbon capture, utilization and sequestration. Specifically, we see a need to advance commercialization through a large scale CO_2 transportation networks now. Regional and then national, large-scale CO_2 pipeline networks would act as the foundation for the CO_2 economy, moving CO_2 from emissions sources to commercial uses. Your leadership has created the 45Q

tax incentive to help make the capture technology economic and widespread. We look forward to working with you on solutions to incentivize the buildout a robust national CO_2 transport network to move this CO_2 to utilization or safe, permanent geologic storage.

Looking forward, we at Occidental are exploring three bold challenges:

1.) Growing our oil and gas production and reserves in an economic and low-cost manner.

2.) Making significant progress toward achieving 'carbon neutrality' for all of Occidental Petroleum, inclusive of the emissions generated from the use of Oxy products.

3.) Operating in a safe manner that respects the environment and our neighbors.

Again, we are focused on meeting a lower carbon energy and product demand. Today, we have a tremendous commercial appetite for CO_2 for use in EOR. But we see EOR and CCUS as a platform for tomorrow, enabling innovation for new and sustainable business models. We have spent the past few years working with employees, shareholders, investors and the leadership team at Occidental to discuss climate change and solutions. And we believe that CCUS and the innovation spurred by investment in CCUS and EOR represent a significant pathway to the most challenging issues of our time – protecting our climate while advancing our economy and supplying low cost energy solutions.

I would like to end by thanking you for the opportunity to speak to you today about an issue that our CEO, our employees and I am passionate about. I look forward to helping answer any questions that you may have.

The CHAIRMAN. Mr. Jackson, thank you very much, we appreciate that.

Mrs. Lagano, thank you.

STATEMENT OF JUDITH LAGANO, SENIOR VICE PRESIDENT OF ASSET MANAGEMENT, NRG ENERGY, INC.

Mrs. LAGANO. Thank you.

Chairman Murkowski, Ranking Member Manchin, members of the Committee, I am honored to be here today testifying on CCUS and the role it can play in reducing greenhouse gas emissions. Thank you for your leadership on this issue, including the introduction of S. 1201, the EFFECT Act.

My name is Judith Lagano and I'm Senior Vice President of Asset Management for NRG Energy, Inc., a large, publicly traded, competitive power company.

At the outset, I'd like to provide some context of what it means to be competitive in the electricity sector. It means that NRG does not have captive ratepayers from whom we can recover costs or guaranteed returns. Our shareholders, not our customers, bear the risk tied to our power plants. We have to compete for our customers and we are proud of the services that we provide to them.

Our company is also proud to be a leader in addressing climate change. We have established targets to reduce our carbon emissions 50 percent by 2030 and 90 percent by 2050. We are ahead on meeting these goals and we are making business decisions to meet them in an affordable and reliable way.

This morning I want to focus on carbon capture, utilization, and storage, our perspective on Ranking Member Manchin's bill, the EFFECT Act, and NRG's experience at Petra Nova, the only commercial-scale CCUS project in the U.S. and the largest in the world.

Petra Nova became operational on December 29th, 2016, on time and on budget. It captures CO_2 from NRG's WA Parish power plant, located southwest of Houston, Texas. We use an amine-based, post-combustion technology to capture 90 percent of the CO_2 from a 240-megawatt equivalent slip stream of flue gas from a coal-fired unit at the plant. The captured CO_2 is then compressed and transported 81 miles via pipeline to the West Ranch Oil Field where it is injected to enhance oil recovery and ultimately sequestered in the oil field. As of the end of April 2019, the plant has delivered almost three million tons of captured CO_2, equivalent to pulling almost 600,000 cars off the road for a year. From an engineering perspective, the project has been a great success.

To help finance and achieve the technological goals of the project, NRG partnered with JX Nippon, a global oil and gas company, in a 50/50 joint venture. Additionally, Petra Nova formed a joint venture with Hilcorp Energy, a privately held oil and gas company to use enhanced oil recovery to increase oil production at the West Ranch Oil Field. The revenue generated by the sale of oil from that field is used in turn to service the project's debt and fund going forward cost. We are parties to the third partnership as well and one that is very important to this Committee.

Petra Nova would not exist without support from the U.S. Department of Energy which provided $190 million cost share grant

to defray the project's approximately $1 billion price tag. That support was made possible by Congress authorizing and funding programs very similar to those authorized in the EFFECT Act.

As with any first of a kind effort, we have learned several lessons from Petra Nova. We have gained a valuable understanding of the challenges presented by scaling up to commercial scale, the impact of location specific considerations such as ambient temperature and the capital and operating costs, along with options to reduce or manage both.

What we have learned has, of course, been shared with DOE and provides valuable insights for the next generation of CCUS projects. The EFFECT Act does a good job of providing the authorities needed for DOE to advance the next generation of CCUS through additional public-private partnerships.

As the bill moves forward, we encourage the Committee to position the Federal Government as an active partner in making projects work from both an engineering and a business perspective. One way to strengthen these partnerships would be allowing DOE's Loan Program Office to refinance project debt. As technologies are proven, they become less risky which should allow for lower cost financing. This could provide a shot in the arm to projects that are demonstrating new technologies but also working to prove that they can operate profitably. I would also encourage this Committee to collaborate with the tax writing committees to ensure that the 45Q tax credit is implemented in a way that provides flexibility around eligibility for and the receipt of the credit.

The EFFECT Act, in combination with other policies that I have mentioned, can help and will help to continue advancing commercial scale CCUS by facilitating technological improvements to drive capital and operating costs lower, the ability to sell CO_2 for enhanced oil recovery and other uses at competitive prices and access to tax credits that can improve project economics.

We applaud the Committee for remaining engaged, both on the challenge presented by climate change and on deploying the technologies needed to solve that challenge. At NRG, we are also committed to being a part of that solution.

We thank you again for the opportunity to appear this morning and I'm happy to answer any questions that the Committee may have.

[The prepared statement of Mrs. Lagano follows:]

NRG Energy, Inc.
804 Carnegie Center
Princeton, NJ 08540

May 16, 2019
TESTIMONY of MRS. JUDITH LAGANO
Senior Vice President of Asset Management
before the
U.S. Senate Committee on Energy & Natural Resources

Hearing to examine the Department of Energy's carbon capture, utilization, and storage (CCUS) programs and to receive testimony on S. 1201, the Enhancing Fossil Fuel Energy Carbon Technology Act of 2019.

Chairman Murkowski, Ranking Member Manchin, members of the committee, I am honored to appear today to testify on the issue of climate change generally; carbon capture, utilization and storage specifically; and what we can do as a country, using market forces and public-private partnerships, to reduce the greenhouse gas emissions that are responsible for our changing climate.

My name is Judith Lagano, and I'm the Senior Vice President of Asset Management for NRG Energy, Inc., a large, publicly traded competitive power company.

What does it mean to be a competitive power company in the electricity sector? It means that NRG is not a rate-regulated utility and, therefore, does not have captive ratepayers from whom we can recover costs or a guaranteed rate of return on the capital that we invest. We have to earn our customers. And our shareholders – not our customers – bear the risks associated with the power plants and other projects that we build and operate.

Our company is proud to be a leader in acting to address climate change – even in the absence of a comprehensive, federal approach. We have embarked on that effort by establishing science-based greenhouse gas emission reduction targets to reduce our carbon emissions 50% by 2030 and 90% by 2050. We provide granular and public disclosure of our progress towards meeting those targets. And we are making the business decisions that are required to meet those targets in a way that provides consumers with the affordable, reliable and increasingly cleaner electricity they want while generating a return for our shareholders.

I am pleased to be here today sharing not only what we have done as a company, but what we believe the federal government can do as well, to facilitate broader participation – from energy companies and consumers alike – in the actions that are needed to mitigate climate change. This morning, I will focus my testimony specifically on carbon capture, utilization and storage; our perspective on Ranking Member Manchin's bill, S. 1201, the EFFECT Act; and NRG's experience with Petra Nova. I will be providing some background on Petra Nova, discussing the lessons we have learned there, underscoring the importance of public-private partnerships, and sharing a

few policy ideas that are not already incorporated into the legislation that is before the committee this morning.

I. Background on Petra Nova

Petra Nova captures carbon dioxide from NRG's WA Parish power plant, which is located southwest of Houston, Texas. The Parish plant has ten coal-fueled and natural gas-fueled units and has a total capacity of 3,653 MW, which makes it one of the largest power plants in the country. Petra Nova uses an amine-based post-combustion technology to capture 90% of the carbon dioxide from a 240 MW equivalent slipstream of flue gas from Unit 8, a coal-fired unit. The captured carbon dioxide is then compressed and transported 81 miles via pipeline to the West Ranch oilfield where it is injected to enhance oil recovery and ultimately sequestered in the subsurface geology of the field.

To help finance and achieve the technological goals of the project, NRG partnered with JX Nippon—a global oil and gas company—in a 50/50 joint venture. Additionally, Petra Nova formed a joint venture with Hilcorp Energy, a privately held oil and gas exploration company, to leverage the untapped potential of the mature West Ranch oilfield. Given Petra Nova's ownership in the oilfield, oil revenues, not the sale of CO_2, are necessary to service the project's debt and fund going forward costs.

Petra Nova would not exist without its partnership with the U.S. Department of Energy, which provided a $190 million cost-shared grant to defray the approximately $1 billion price tag for the Petra Nova partners' investment in the carbon capture facility and their share of the oilfield improvements.

Petra Nova became operational on December 29, 2016. I am very proud of the development of the project, which resulted in the system coming online, on budget and on schedule. Since starting operations, the plant has captured almost 3,000,000 tons of carbon dioxide used for enhanced oil recovery providing the dual benefit of removing CO_2 from the atmosphere while boosting the production of domestic oil and the United States' goal of energy independence.

In 2017, Petra Nova received recognition as both the Project of the Year and the Coal-Fired Project of the Year, awarded by Power Engineering. Overall, the project represents an accomplishment for cleaner energy today and a proven vision for how we can enhance sustainable coal-powered technology for the future. This achievement has captured interest from all over the world as we and the Department of Energy have hosted hundreds of visitors each year from both industry and government, including just recently, Senator Manchin.

II. Technical and Economic Advancements in Commercial Scale CCUS

As with any first-of-a-kind effort, we have learned several lessons from Petra Nova. Specifically, we have gained a valuable and more detailed understanding of the challenges presented by scaling up carbon capture to commercial scale; the impact of location-specific considerations,

such as the effects of ambient temperatures; and the costs – both capital and operating costs – along with options to reduce or manage both.

Petra Nova is the only U.S. facility capturing CO_2 in large quantities (over 1 million tons per year) from a fossil-fueled power plant. In the United States, small-scale pilot projects have been more typical. At ten times the size of Plant Barry, along with the unique challenges of Houston's summer conditions, Petra Nova deployed technologies and mechanical equipment that stressed normal industry standards. As you would expect, an increase in scale necessitates technical solutions to accommodate unique design challenges. Working with our technology provider, Mitsubishi Heavy Industries America, we have encountered and solved for a variety of challenges.

For example, maintaining the proper temperatures in the process is critical for the amine to capture and subsequently release the CO_2. The use of amines to capture CO_2 has been well proven in other applications; however, the large scale of the Petra Nova project combined with the previously mentioned high ambient conditions created the need for numerous large heat exchangers, both plate-and-frame and shell-and-tube designs, to properly control temperatures inside the process. While both styles of heat exchangers have been used successfully for many years in industrial applications and in the presence of amines, the projects designers had to work diligently to ensure the long-term viability of the exchangers while providing the needed cooling capacity.

Additionally, information gathered from operating projects can assist engineers in understanding how advanced solvents and sorbents will perform over time. For example, understanding their rate of degradation and the impact on both the carbon capture system components and process efficiency can provide valuable insights for the next generation of carbon capture.

The project has also generated valuable information that could be useful to the committee and future developers, given Petra Nova's location on the Gulf Coast, ambient conditions, its specific altitude, the use of Powder River Basin coal, and the geology for enhanced oil recovery unique to the Gulf Coast.

In combination, these factors impact the overall project performance and economics. In some cases, they are helpful factors and on others they have revealed that certain conditions could be optimized in second- third- or fourth-of-a-kind projects. This data can be used to optimize equipment size, cost, and efficiency so designers can balance engineering solutions and capital constraints. Unique to our location on the Gulf Coast, specific knowledge can be gained from enhanced oil recovery efforts in Frio formations found in the Gulf Coast rather than the more prevalent formations used for enhanced oil recovery in the Permian Basin.

At the West Ranch oilfield, we are gaining experience regarding how an EOR flood performs by tracking and evaluating information such as the amount of gas required to produce a barrel oil (commonly called the gas-to-oil ratio); the pressure needed for the CO_2 to properly mix with the oil (called minimum miscibility pressure or MMP); the proper spacing for injection and production wells; the timing to alternate between injecting water and CO_2 and the amounts for each (a

process called "water-alternating-gas" or WAG); the impact of unique reservoir characteristics, for example dealing with sand and methane in the production process; and the balance between capital and operating expenditures and production. An example of a specific R&D effort at West Ranch is the partnership between the oilfield partners and Japanese companies to pilot new membrane technologies to remove methane from recycled CO_2 and to determine if it can be deployed at commercial scale. JOGMEC, a Japanese governmental institution, provides financial support.

Regarding the plant economics, project costs are only partially defrayed by our partnership with the federal government and must be, in any case, carefully managed to ensure the viability of CCUS as it is incorporated into our energy mix. Petra Nova is unique in that we have an ownership interest in a single oilfield; whereas typical oil companies diversify their risks over several holdings. We would expect that for CCUS to be commercially successful in the future, it will be important for power generators to partner with oil companies in the form of a "fence line" sale of CO_2. The likelihood of producers and consumers of CO_2 to transact under such terms will improve as greater economies are realized to lower the cost of delivered CO_2. Financial support for research and development proposed in the EFFECT Act can greatly assist in this endeavor to drive down the cost of producing CO_2 from carbon capture.

III. The Role of Partnerships

We are fortunate to have partnered with the federal government to further the science and economics of CCUS. In terms of technical expertise and financial support, it is certain that without public-private partnerships for large-scale applications of developing technologies, projects like Petra Nova don't happen. The EFFECT Act, and its predecessor legislative efforts recognize this basic fact. The bill appropriately suggests reauthorizing and expanding upon authorities needed to continue driving interest in and support for projects like Petra Nova. This is critically important for new projects.

Another perspective that we would encourage the committee to evaluate are authorities that would allow the federal government to remain a more active partner in making these projects work, from both an engineering perspective and a business perspective. If the business proposition cannot be proven then we are left with nothing more than an interesting experiment, while climate challenge requires a portfolio of technological options that can stand on their own and compete against more conventional and GHG-intensive approaches to generating electricity.

We hope that the country proliferates CCUS projects, and that Petra Nova can provide a foundational piece of the knowledge required to do so. But we think there is more the government can do, and more that the EFFECT Act can do, to recognize the importance of remaining a partner. So I'd like to pivot from policy and commercials lessons learned to a handful of new or additional ideas that we believe the committee should consider as it considers and advances the EFFECT Act and similar bills.

IV. New Policy Ideas.

Consistent with doing more to sustain partnerships between the federal government and the private sector for projects like Petra Nova, I would like to offer some policy ideas as the committee contemplates building upon the important policies contained in the EFFECT Act. I have tried to confine these ideas to changes that would be jurisdictional to the committee, but in the case of 45Q I have addressed issues related to the internal revenue code.

One option for ongoing support of projects like Petra Nova would be to amend the underlying authorities for the Department of Energy's Loan Programs Office to allow them to refinance debt associated with projects that are subject to a public-private partnership. Such a change would recognize that as technologies are proven at commercial scale, they become less risky. Improving the financing terms and conditions tied to project debt could provide a shot in the arm to projects that are not only working to demonstrate technologies but also to prove that they can operate profitably. This is particularly important in a state like Texas, which has a very competitive electricity market, and for companies like NRG that have no captive ratepayers from whom costs can be recovered or rates of return that are oftentimes guaranteed by public service commissions in other markets.

As stated above, one issue to consider in contemplating the second-, third-, or fourth-of-a-kind demonstration is the locational differences that a project encounters depending upon where it is sited. In legislation, this could be addressed by simply encouraging the relevant federal agencies to consider the benefits of demonstrating projects in geographically diverse locations, to facilitate learning as we gain experience with technologies operating in a variety of ambient temperatures, altitudes, proximities to storage or utilization for captured carbon dioxide including the availability of common carrier pipelines, and other factors. The committee has authorized such an approach in the past (e.g., in Sec. 413 of the Energy Policy Act of 2005, which included altitude as part of its eligibility criteria for demonstration) but, frankly, funding levels have not tended to be sufficient to demonstrate a wide variety of projects in a wide variety of locations.

Lastly, I would encourage members of this committee to collaborate with your colleagues at the tax-writing committees to ensure that the 45Q tax credits are implemented in a way that both recognizes the existence of an already operational facility like Petra Nova and provides flexibility in how eligibility for and receipt of the credit can be kept flexible.

V. Conclusion

In summary, several items are needed for "at-scale" CCUS: (a) technological advancements to drive capital and operating costs lower, (b) alignment between CCUS and EOR operators to sell CO_2 at competitive prices, and (c) flexible mechanisms to access to 45Q tax credits. Parallel to your efforts in looking at the technological challenges, we also support the current efforts of other Government agencies in looking at improving access to 45Q tax credits.

We applaud the committee for remaining engaged not only on the challenge presented by climate change but also on advancing the programmatic authorities needed to demonstrate technologies capable of solving that challenge. At NRG, we are committed to being a part of that solution, we thank you – again – for the opportunity to appear this morning, and I am happy to respond to any questions that the committee may have.

The CHAIRMAN. Thank you, Mrs. Lagano. Thank you all for your testimony this morning.

I am reminded as I listen to this that we have some of the most fun here in this Committee in terms of being able to be updated on what is happening with the technologies out there that are really making a difference. Not only making a difference from the access to energy, the affordability, but what we are doing to advance measures that truly are more clean.

I don't know why it should be so revolutionary to think that this is all about management, but I have heard each of you—Dr. Friedmann, you articulated it very clearly; and Mr. Goff, you followed on it; and Mr. Harju said, we are not in a carbon constrained world, but rather a world of carbon management. And how we manage this in different ways is really starting to make a considerable difference.

Whether it is the deployment with what you have out there at Petra Nova in Texas, what is coming on with Project Tundra, or what you are doing with NET Power, you all are managing carbon in different ways because you do not have the same assets in every location.

Mrs. Lagano, you mentioned that the impact of location is key. I am curious about the ambient temperature. I hadn't thought about things like that. I think about where you have geologic areas underground that you can utilize but it is just, again, a reminder that managing is going to look different depending on where you are.

We get this mindset back here in Washington that we can just check off a series of steps that you can take, and we are going to all be utilizing this same process and it is going to work everywhere. It just demonstrates that we are not the scientists and the engineers. You all are, and we need to be listening to you.

So, Mrs. Lagano, you have identified some things that I think are important for us to keep in mind, the imperative of 45Q and loan guarantees. Those are some of the things that we can help to facilitate. Oftentimes what we realize is that we, the government, are in the way of some of the important opportunities because we put regulatory impediments in your way and permitting issues in the way, so it's not just the economic challenges.

So, you all have been working to really get things from beyond the drawing room, really, out to application. Mr. Goff, Mr. Harju, Mrs. Lagano, and Mr. Jackson as well at Oxy, what do we need to be doing to clear the path of impediments on the regulatory side, but also some of the economic challenges that you face that we can be helpful at the federal level? And I don't mean to limit it to just four of you, all can jump in, but please go ahead, whoever wants to jump.

Mrs. Lagano?

Mrs. LAGANO. I'll start, yes, thank you.

I think what we could do is that assisting technology providers to drive capital costs lower, right, as we do a project and we learn from, for example, NRG's experience scaling up. How can we use that for the next project to reduce cost and drive, ultimately, the cost of delivered CO_2 down?

The CHAIRMAN. How do you share that with others so that they gain the benefit of your taking the first step?

Mrs. LAGANO. Yeah so, in working closely with the DOE, we are providing information to them regularly about the challenges that we face and we solve. And we do that in a cooperative environment and a collaborative environment with the DOE so that the benefit of our experiences can be used for the next generation of technology, and frankly, to enhance our own existing project.

The CHAIRMAN. Others? Mr. Jackson?

Mr. JACKSON. Thank you very much. I think I can speak to that, and I appreciate those comments.

You know, for us, 45Q was certainly a significant step. I think not only the enhancements that were created out of 45Q, but the longevity created investible projects, both for technology and ultimately CCUS.

I think we agree that R&D in the technology and especially from the capture can do a lot to promote the available low-cost supply of CO_2 that we can ultimately use in a productive way.

Beyond that, we think R&D around utilization is important. So today we talk mostly about enhanced oil recovery, but I think for this to collectively work, more utilization opportunities should exist.

The CHAIRMAN. Outside of EOR?

Mr. JACKSON. Exactly.

And ultimately what that does is create not only the source, but the sink, as we've described it, which enables infrastructure.

And so, for us, we look today and we believe there are many commercial projects that are ready to go with available technology. We're looking at projects in the Midwest with ethanol, very low cost of capture and really the enabling source will be infrastructure.

So again, lowering cost, increasing utilization, but ultimately creating this infrastructure for us, we see very near-term capabilities with CCUS at large scale.

The CHAIRMAN. Others? Mr. Harju?

Mr. HARJU. Yes, thank you.

I would certainly concur with appreciating remarks, but one thing that we see that under today's guidance the 45Q credit can be challenging for some to claim. And we're encouraged by the solicitation of comments that IRS has recently announced, and we're hopeful that some malleability in terms of the means by which one would document secure geologic storage can come to the table.

The CHAIRMAN. Okay, good to know.

Mr. Goff?

Mr. GOFF. Two things to add here.

One, one of the reasons we think 45Q is such a critical incentive is it allows you to learn by doing and by building two or three of the same technology, you know, in a row, you really can drive down capital cost that allow you to build that without that incentive anywhere in the world.

And then secondly, on Richard's point on infrastructure, the way we view the carbon capture industry, what's good for one technology is good for everyone else. Anytime someone builds a carbon pipeline or has a carbon offtake, that's somewhere where we look

to develop a project. So anything that we can do to develop more carbon projects, to build more carbon pipelines. We currently have 5,000 miles of carbon pipelines. We need more. Then it helps us build projects on top of that and, you know, develop an entirely new industry around using carbon.

The CHAIRMAN. Dr. Friedmann?

Dr. FRIEDMANN. Thank you.

If I may add, first, quickly to underscore two of the points that have been made. One of them is, again, on this infrastructure issue. We could get about 40 million tons of carbon dioxide underground today if the pipelines existed, and they don't. Second is capital treatments. That's really essential. These are big capital projects, and it's hard to get your return on these things.

But it doesn't just have to be something like the 45Q tax credits. There's ITCs. There's Economic Opportunity Zones. There's accelerated depreciation. There's lots of tools that could be used potentially to improve the capital profile of projects like this and help get more of them into market.

The one I would add to that though is that we have a few bills already floating around Congress that can deal with some of these things. The USE IT Act is the most obvious of these in terms of helping to accelerate pipeline deployment. We have Senator Smith's Clean Energy Standard that was put on with Representative Luján.

Those are all things that can really substantively contribute to getting this technology to market. And it's entirely, in my mind, the costs and the technologies are already in a pretty good place. They certainly could be better, but it's really about finance now. These projects can't be financed readily, and that's where the policy support will prove most important.

The CHAIRMAN. Thank you.

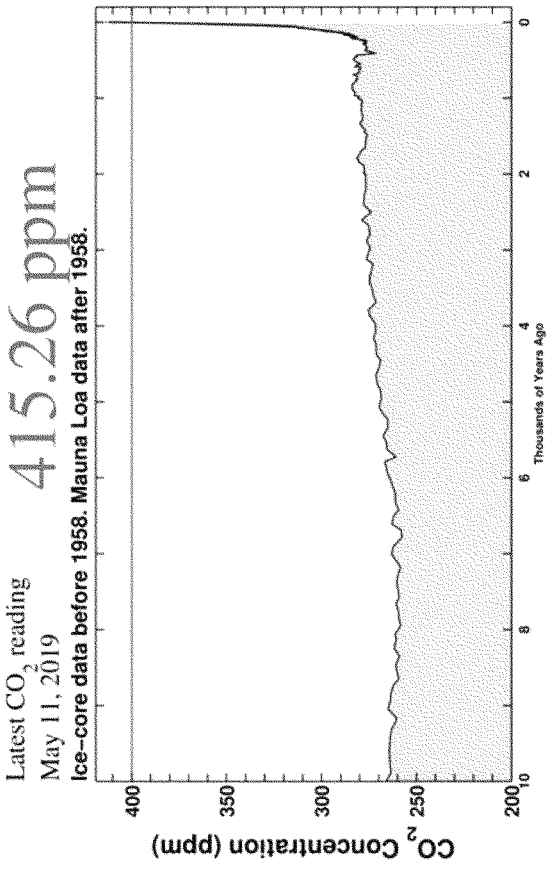
Senator Manchin.

Senator MANCHIN. I am going to defer to my "carbonated" friend, Senator King.

Senator KING. Thank you. I have an Armed Services Committee meeting coming up.

I want to provide a visual coda to the Chair's very thoughtful introduction and that is, why are we here? I am going to have one that will show it a little bit better. But this is 10,000 years of CO_2 in the atmosphere. It is a little hard to see because the hockey stick is so steep, but where we are is at the very top of the chart now.

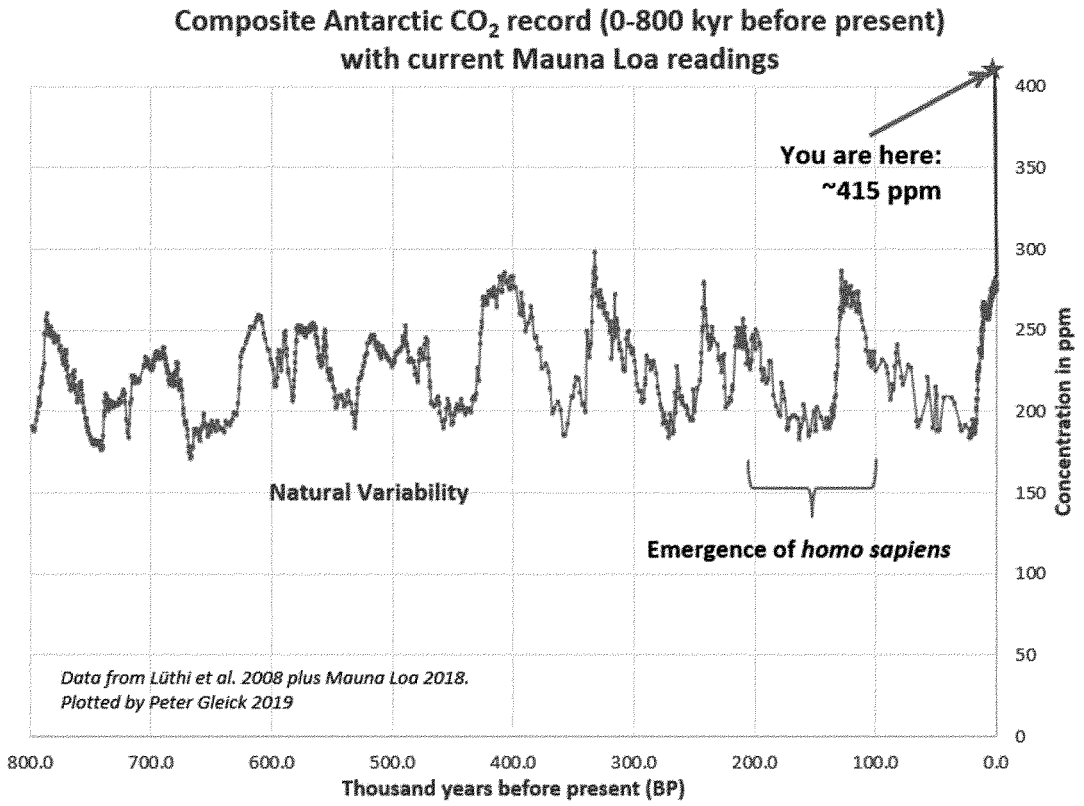
[The information referred to follows:]


Latest CO_2 reading
May 11, 2019
415.26 ppm
Ice–core data before 1958. Mauna Loa data after 1958.
CO_2 Concentration (ppm)
400
350
300
250
200
10
8
6
4
2
0
Thousands of Years Ago

Senator KING. You can see we have gone from an average of about 240 parts per million 10,000 years ago to 415 last week.

Here is another one that, I think, puts it in even more perspective. This is 800,000 years of CO_2 in the atmosphere. And what it shows is yes, there are variations over time, but we're now, again, where the red arrow is, at a place that we haven't been for three million years.

[The information referred to follows:]


Composite Antarctic CO_2 record (0-800 kyr before present)
with current Mauna Loa readings
You are here:
~415 ppm
Natural Variability
Emergence of *homo sapiens*
Data from Lüthi et al. 2008 plus Mauna Loa 2018.
Plotted by Peter Gleick 2019
Concentration in ppm
400
350
300
250
200
150
100
50
0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
Thousand years before present (BP)

Senator KING. The last time we were at this level of carbon, the oceans were 60 feet higher and there were jungles in Alaska—that is why there is oil there.

So we are really in a very dangerous place, literally. We have never been here before in terms of human history. So I just think it is important to—I am a visual learner—to see where we have been for 800,000 years and where we are now. And it really makes this hearing, I think, a very important hearing and I commend the Chair and the Co-Chair for bringing this forward.

My question is, what is our target? I think one of you mentioned, several of you have mentioned, 24 metric tons and 300 metric tons. How many metric tons of carbon are released every day or every week or every year in the world? I mean, we need to know. I need to get a feel of what the target is.

Doctor?

Dr. FRIEDMANN. So if it's just CO_2, right now we're emitting 34 billion tons of CO_2 every year. To give you a sense of scale, one billion tons is twice the weight of all the human beings on earth. So we're emitting 70 times the mass of humanity every year in terms of CO_2. When you add the other greenhouse gases, it's 53 gigatons of CO_2 equivalent.

Senator KING. So that is the target.

What this chart tells us is we could go to zero emissions tomorrow, and we are still in a hell of a mess. And we have to start talking about not only controlling emissions, which is urgent, but also pulling out what is already in the atmosphere. Is that technology at a place where it is becoming economically feasible?

Dr. FRIEDMANN. Yup, the National Academy has just wrote a very substantial report on this. It looked at all of the pathways for CO_2 removal, including natural pathways like forests and——

Senator KING. Forestation?

Dr. FRIEDMANN. Bio energy with CCS, including ethanol and direct air capture and mineralization. They also looked at carbon storage as something that encourages or makes all of that possible.

The short answer is given today's technology basket, the U.S. can't get there. So we need to expand and accelerate.

Senator KING. Therefore, R&D.

Dr. FRIEDMANN. Therefore, R&D on all of them. And they proposed a budget of about $900 billion a year across all of those technology pathways, in multiple agencies, including the Department of Energy in the Office of Fossil Energy and USDA.

Senator KING. You said $900 billion?

Dr. FRIEDMANN. I'm sorry, $900 million, my apologies. That was a mistake, please amend the record there. So less than $1 billion a year.

Senator KING. But this is one of the most significant areas of research. It seems to me that this and energy storage are the two great challenges that we have to face.

My second question is, and I think you answered this in your discussion of projects, can this be done economically? How many cents per kilowatt-hour does it add to the cost of the power that plants are producing? Is it one cent, two cents, three cents? I used to be in the energy business, and I think in terms of cents per kilowatt-hour.

Mr. GOFF. So for NET Power, we're a bit different because carbon capture is inherent in our system so we can't not capture it. And for us we don't think there's going to be any premium.

Senator KING. So your energy can be sold competitively with other garden variety natural gas plants or——

Mr. GOFF. At the same cost or lower.

The thing that gives us an advantage is we don't only sell power. We're competing against power plants to make all that money selling power. We sell CO_2. We sell Argon.

Senator KING. You have a second line of revenue.

Mr. GOFF. We've got four revenues, yes. Argon, nitrogen, CO_2 and power.

Senator KING. Sir?

Mr. JACKSON. I just wanted to underscore the first four. I think when we looked at this from a strategic level we came to the same conclusion. We made, obviously, industrial capture holds tremendous promise for the world when you think about exporting technology and how do you impact this globally, I think, industrial capture can absolutely do that.

But we realized to make significant impact on reduction of atmospheric greenhouse gas, direct air capture held tremendous promise. So we made an investment in carbon engineering, a direct air capture technology and we're excited about the viability of that technology.

I think, the other thing I wanted to point out earlier, is I think this is a great example of partnership and we view it across value chains.

So, you have the capture technology. You have the transportation component which we've talked a lot about.

Yet the utilization and I think where you can come together, you know, a company like ours can work with NET Power or can work with carbon engineering in a direct air capture plant and we can find value. How do you finance it? How do you construct it? How do you put the business purpose together? And so, we're very excited about what we think is coming over the coming years on both sides of that solution.

Senator KING. Madam Chair, the only thing I would add is that this has to be international.

The CHAIRMAN. Absolutely.

Senator KING. We have to. If we develop these technologies, they should be shared because we can do everything in the world here, but if it doesn't happen in India and China, we are not going to deal with this problem.

So I appreciate very much your being here and hope you can continue to inform the Committee on this incredibly important subject.

Thank you.

The CHAIRMAN. Senator King, I will allow you a little bit of an extension of time if you want to ask that very pressing question about what are we doing with technology sharing?

Somebody mentioned that China has one of the operating, or I don't know whether it is commercialized. It was you, Dr. Friedmann. You said here in the United States we have eight. China has one. What are we doing on technology sharing for this?

Dr. FRIEDMANN. I'll defer to Assistant Secretary Winberg, first.

Mr. WINBERG. So there are a number of efforts that the Department of Energy is engaged in.

One is the Clean Energy Ministerial which is countries from all over the world. In fact, in a couple weeks, Secretary Perry will be attending that meeting up in Vancouver. There's also the Carbon Sequestration Leadership Forum. So there's a number of venues that we're working through to commercialize, to share technology, to share best practices, not only in capture, but also in the movement of CO_2 and, of course, storage.

Senator KING. This may be the one place where we want the Chinese to steal intellectual property.

[Laughter.]

No.

Mr. WINBERG. Well, I don't know that I'd go that far, sir, but——

Senator KING. Just saying.

Mr. WINBERG. ——the Chinese are moving forward on this as well.

But it takes a whole suite of technologies and, from capture technologies, reducing the cost is important. We've talked about direct air capture, very important, but there's, it's a concentration difference.

What's coming out of a coal-fired or natural gas stack, coal-fired stack is 140,000 parts per million versus 400 parts per million in the air that we breathe.

So the low hanging fruit is capturing the CO_2 at the source, at the stack, if you will. But direct air capture can be utilized geographically, broadly. It's expensive. We are working on a number of technologies to bring that cost down. But it is a suite of technologies.

Senator KING. I would urge the Department to work as cooperatively as possible with the international partners. This is a worldwide problem, and it deserves a worldwide concentration of effort.

Mr. WINBERG. Yes, sir, we are.

Dr. FRIEDMANN. You may be pleased to know that the Clean Energy Ministerial is, in fact, an essential platform and the DOE is showing real leadership on pulling that together.

The International Energy Agency is now the organizing secretariat for the CCUS mission and, in fact, Director Birol is passionately committed to that and has raised that to make it part of that Ministerial.

In addition to that, there is a CCUS Knowledge Centre based out of Saskatchewan. They share the engineering data and geological data from the results of their project at Boundary Dam and Petra Nova is party to that, as are other projects.

The International Energy Agency's Greenhouse Gas Secretariat publishes exhaustively on this topic and shares results widely through a network. And there are many bilateral agreements as well between the United States and Norway, the United States and Netherlands, United States and the United Kingdom and in China and Japan. This is work that's being done.

When I served in government I learned, much to my dismay, that the U.S. didn't set policy in other countries.

[Laughter.]

And as a consequence, we really have to approach any country and any opportunity as a potential partnership and really trying to figure out how to meet them on their terms and understand where they live. India is in a very different place on this technology than the Netherlands, and we have to understand and conscious that if we want to make progress.

One last word, we should be engaging the international financial community on this topic. We should be meeting in Davos. We should be raising it in those kinds of platforms as well.

Senator KING. Thank you.

Thank you, Madam Chair.

Mrs. LAGANO. I'd actually like to add——

The CHAIRMAN. These discussions are going on in the Arctic sphere, in the international forum and what we need to be thinking about in terms of financing.

Dr. FRIEDMANN. Both the Arctic Circle and——

Senator KING. Mr. Harju used a term that I don't think ever has been used in these halls before. He used the term malleable in the same sentence with IRS. I don't think that has ever been done.

[Laughter.]

The CHAIRMAN. Quotable.

Mrs. Lagano.

Mrs. LAGANO. Yes, thank you.

So I'd like to point out from Petra Nova's perspective CCUS is already an international effort with our partnerships between American companies and Japanese companies, JX Nippon, as well as lending from the Japanese bank, NEXI, and JBIC. And we agree that given the global effects of climate change that it is not only good business, but it's essential that this technology be exported.

And at Petra Nova we have hosted hundreds of visitors from around the world that are interested in the technology that we deployed. So we think Petra Nova is an example of how this already is a very extensive international effort.

The CHAIRMAN. Dr. Cassidy.

Senator CASSIDY. Hi, Mr. Winberg. I just came back from Louisiana with President Trump. We looked at Sempra sending so much natural gas around the world. If I can quote the President, "Put a big, big, beautiful plant."

So it is clear that gas is going to play a major role, not just in our energy generation but that which is around the world.

Now a lot of our CCUS seems to be focused upon coal, so what is DOE planning in terms of research to take CCUS and apply it to natural gas as opposed to coal?

Mr. WINBERG. Thank you.

Virtually all of the technology, the capture technology, that we've been developing is equally applicable to natural gas.

Senator CASSIDY. But I am told the chemistry is different, so there are challenges with gas that is not present with coal.

Mr. WINBERG. There's some different constituents between coal and gas, in the coal and natural gas exhausts, but that can be accommodated for. It's also more dilute stream in natural gas.

We are issuing a $30 million FOA for a feed study for carbon capture and that will be one for coal and one for natural gas. Also the National Carbon Capture Center that we run with Southern

Company is installing a natural gas facility so that carbon capture technologies can be tested down there using natural gas. They could also be tested using coal.

The other comment that I would make, or the other thought I have, is on the sequestration that a molecule of CO_2 from coal or gas doesn't really care whether how it's put into a pipeline or where it's sequestered. So, the activity that we have done in the area of sequestration subsurface characterization is equally applicable to natural gas.

Senator CASSIDY. Got it.

So let me ask though, the knock on CCUS for coal is that it detracts from the energy production and/or raises the cost of operating the plant. What impact does carbon capture have upon the cost basis of the energy produced by a natural gas, say, combined cycle plant or a traditional plant, two different cost bases and/or what is the detraction from the overall energy output or the efficiency of energy production?

Mr. WINBERG. There's a capital cost and there's an operating cost associated with CCS on natural gas, not the case necessarily with an Allam Cycle, but with a conventional natural gas combined cycle, there is.

But with the 45Q and the opportunity to capture that CO_2 and then use it for enhanced oil recovery, there's a $35 per metric ton tax credit, and if it's sequestered in deep saline formation there's a $50 tax credit.

In the EOR space we're quite confident——

Senator CASSIDY. So, wait a second. You are telling me that which would offset the cost.

Mr. WINBERG. Yes, sir.

Senator CASSIDY. But how much would be the cost and/or the decrease in efficiency if you apply this technology to natural gas? Do you see what I am saying? Because clearly there is a cost because you are telling me well, we need the 45Q and the $50, et cetera.

Mr. WINBERG. Probably about a 20 percent decrease in the efficiency of the natural gas combined cycle because of the parasitic power you need.

Senator CASSIDY. Okay. That is significant.

Mr. WINBERG. Yes, sir.

Senator CASSIDY. Do you need any additional authorization from this Committee to further the—because you mentioned that there is some of the same stuff you are doing for coal that can also be applied to natural gas—but do you need more resources to more robustly build this out?

I just say this because, again, the U.S. feedstock is increasingly natural gas and as I see Sempra, Venture, Magnolia, Cheniere and others shipping this gas around the world and we share technology, that research wants to be furthered.

Do you need this Committee to do more in terms of facilitating that research?

Mr. WINBERG. We could always use a little bit more money.

[Laughter.]

Senator CASSIDY. You sound like my daughter.

Mr. WINBERG. But I think the portfolio of technologies that we have under development right now is adequate in both the coal and the natural gas space.

One of the concerns or issues that has been raised by my fellow panel members is, of course, the infrastructure, perhaps not the domain of this Committee, but infrastructure to a CO_2 pipeline infrastructure to be able to move the captured CO_2 into those areas where it can best be used for enhanced oil recovery or for storage.

Senator CASSIDY. Now I am from Louisiana so we actually have that—Denbury has a pipe that goes down 190. That is pretty close. Now granted, it is coming from Jackson, Mississippi, but it is close to our industrial base. So it theoretically could be addressed——

Mr. WINBERG. Yes, sir.

Senator CASSIDY. ——with just a little bit of add-in.

Mr. WINBERG. There's about 5,000 miles of CO_2 pipeline currently in the United States. There's some estimates that we need anywhere from 10,000 to 30,000 miles if we're going to make significant reductions in CO_2 emissions from fossil energy sources.

Senator CASSIDY. Okay.

Well, I am over time. I yield back. Thank you.

The CHAIRMAN. Thank you, Senator Cassidy.

Senator Manchin.

Senator MANCHIN. Thank you, Madam Chairman.

In a perfect world, which we do not have, people are taking one side or the other. I think there is an elimination mentality.

You all can help us immensely, basically, to understand what we are dealing with. There are people, and I would say probably the scientists and experts, a lot like yourselves, who might be on the other side of the fence thinking that we should not be doing and talking about carbon capture because we should be moving to other fuels. So you wouldn't have to have carbon capture. There is that type of a thought process.

You all are speaking on the reality in the terms of what is happening in the world. It is not just in America. It is called global climate. It is not called North American climate or the United States climate. They have to understand what is going on, and we have to do something about it to save the planet. I talk to people all the time about it. They say global climate.

Well, in terms of biblical time spans, it is Old Testament, New Testament, it has always been climate change. But when you talk in scientific terms, as far as the last century, there is no doubt that humans, as I think Senator King's diagram there showed, humans have had a tremendous impact. And it is up to us.

So I keep thinking we need carbon capture and sequestration. We are talking about 30,000 miles of pipeline on and on and on. Is there not feasible technology that can solidify carbon, solidify the waste stream? We have to take the gas as we turn it into liquid now. Can it not be solidified to be used in a different form so you don't have to transport it? I am thinking outside of that.

Next, I would ask the question, if the clear air or clear, you know, we call it what, direct air capture? If that is put in the area near a power plant rather than retrofitting a power plant, trying to take clear stream carbon off and liquefying it, is that more cost-

effective, or could it be? Is there any type of technology that has been experimented with?

Anybody? Whoever? Dr. Friedmann, do you want to start? And then Mr. Jackson, come in.

Dr. FRIEDMANN. Yeah, so let me answer your last question first.

Because you're dealing with a more dilute stream of CO_2 from the air as compared to any other fluid stream—this is what Assistant Secretary Winberg mentioned—direct air capture is always borne more expensive.

Senator MANCHIN. Gotcha.

Dr. FRIEDMANN. Many people suggest that that means we should do CCS before direct air capture. I would say the opposite. This is a yes/and and not neither/or. We need to develop both of these technologies, because we need them both and we need them in spades.

With respect to your other question about solidifying CO_2, the near-term application for that is actually turning CO_2 into cement and concrete.

Senator MANCHIN. Yes, I know.

Dr. FRIEDMANN. And there's good technologies to do that now and those companies are scaling fast. It is possible to turn CO_2 into carbon black which we use to make tires and that's a durable carbon into carbon nanotubes. There's, maybe, a dozen companies out there who are working on similar technologies.

Senator MANCHIN. That is not through solidification or——

Dr. FRIEDMANN. Yeah, it's conversion basically, but it's turning into a solid building material and a solid feedstock, all of which is good.

Senator MANCHIN. So that is all doable? That technology is there now?

Dr. FRIEDMANN. It's not—those technologies are not yet commercial. The cement and concrete is. The others need some help. And actually, it's part of the reason why a CO_2 utilization line in the DOE's budget is so valuable.

Senator MANCHIN. Okay.

Mr. Jackson?

Mr. JACKSON. May I just, a few points?

Senator MANCHIN. Sure.

Mr. JACKSON. You know, I think when we look at technologies, we view it over different time horizons and it is, it should be a competitive space to make great commercial technologies, low carbon technologies. And so I do think it takes all-of-the-above and we certainly support that.

I think, when you look at an example of a direct air capture plant near a gas plant, there could be different time horizons. I think, you know, when you look at a technology like NET Power and envision CO_2 infrastructure, I think you can look forward to placing, if you're going to place new, industrial centers anywhere in the world, it should be near utilization or infrastructure.

I think the way you get to the products that you described is through available low-cost use. And I think, you know, there's obviously transportation costs that come on the back end of that product as well. And so oftentimes you need that infrastructure to get

it to a point where their marketing capability and cost is low as well.

Senator MANCHIN. Thank you.

Mrs. Lagano, if I can?

First of all, I want to thank you. I was able to come to—and you all were so kind. I have been to Petra Nova, and I have seen what is feasible.

I was concerned about the cost. And basically, with the Federal Government's help, DOE and everyone's help with that, it still makes it quite challenging. I was also concerned that, even with the enhanced oil recovery, it is still not a viable project financially.

Mrs. LAGANO. So, thank you.

Senator MANCHIN. So I am concerned about that. Have we advanced and learned enough off of Petra Nova how to do it and make it more cost-effective? Because give me the oil recovery in the fields you have entered into before and after the injection.

Mrs. LAGANO. Yes, so thank you, Senator Manchin. It was a pleasure to have you. We're extremely proud of the project, and we love to have visitors come.

Senator MANCHIN. Well, you should be. It is wonderful. And I will tell you, I would recommend if you have not been to Petra Nova, go see it. Go ahead.

Mrs. LAGANO. So oil recovery, enhanced oil recovery, is a very important part of the economics of Petra Nova in terms of the revenues that it generates.

Senator MANCHIN. Cost.

Mrs. LAGANO. So there are a few revenue streams——

Senator MANCHIN. How much did you enhance the field by, just explain that? How many barrels were you getting out of the field before you started injecting?

Mrs. LAGANO. So less than 100 barrels a day, perhaps.

Senator MANCHIN. And where are you now?

Mrs. LAGANO. And multiples of that.

Senator MANCHIN. I thought you were on 3,000 or 4,000 barrels now?

Mrs. LAGANO. We're up from that.

Senator MANCHIN. It is hard. You would think that would be economically beneficial.

Mrs. LAGANO. Yes, so no question that it's working and that is a focus of ours is to maximize the oil revenues from the fields.

And one thing that's interesting about this project, when we talked about, Senator Murkowski talked about, what you learn from specific locations. So in this specific location we are in the Gulf Coast as opposed to the more conventional formations in geology of the Permian Basin where we see a lot of EOR. So we're learning very much every day about enhanced oil recovery in the Gulf Coast and solving the challenges that we encounter in that geology. That's an important learning experience because if we can optimize and maximize oil recovery in new formations, then it opens up the fields of potentially other areas where CCUS can——

Senator MANCHIN. Just one final comment on that.

How much resistance do you all run into when you talk about carbon capture?

Dr. Birol told us the two things that basically could help decarbonize and start helping the global climate would be nukes and CCUS. The two fastest, quickest, most cost-effective things we can do to decarbonize rather than just total elimination, which they are not going to do and we know that. But speaking in terms of reality, how much push back are you getting talking to your friends and colleagues that maybe have another point of view in this?

Mr. Goff?

Mr. GOFF. So our experience on this is we haven't faced nearly any resistance but there isn't nearly enough focus. I think people are used to focusing on technologies that have been around for longer. Solar and wind are——

Senator MANCHIN. I am talking about the concept of the new green deal and the reality of what it takes to be green.

Mr. GOFF. Yeah, so we, I think with NET Power specifically, are confident that we're going to get there with our, you know, friends on the environmental side of things that carbon capture is necessary, but that certainly remains to be seen.

The CHAIRMAN. Thank you, Senator Manchin.

Senator Daines, we have had a great conversation here today.

Senator DAINES. I can see that.

Chair Murkowski, Ranking Member Manchin, thank you for holding this very important hearing. As a co-sponsor of the EFFECT Act, I want to thank the Ranking Member. Senator Manchin, I want to thank you for your leadership in this area and highlight the need for more investment in CCUS.

I think we have a great opportunity, not just investing in clean technology but also in our communities and these good-paying jobs that coal power plants create, very important for Montana, for our country.

As many in this Committee have heard me say before, the Colstrip Power Plant in Montana is one of the largest coal-powered plants west of the Mississippi and one of the largest economic drivers in Montana. A tremendous source of jobs, of reliable low-cost energy, importantly, part of our tax base in Montana that is critical.

I believe that it shares a lot of similarities to the Petra Nova site and is thus uniquely situated for further investment and innovation. Of course, Montana has more recoverable coal than any state in the United States. Colstrip, like Petra Nova, is a large-scale coal plant that with a new pipeline can gain access to a nearby active oil field. We are out in the proximity of the Bakken. There is also strong support from the community and interest from stakeholders to utilize the carbon from Colstrip for EOR activities.

Mr. Winberg, the EFFECT Act creates additional investment opportunities in the DOE for carbon capture programs and demonstrations that I discussed with DOE before in this Committee, and I believe Montana is a perfect location for more investment by the Department of Energy.

My question is, do I have your commitment that DOE will work with me, with the Colstrip community and the owners to find opportunities for investment in Colstrip like those created in the bipartisan EFFECT Act?

Mr. WINBERG. Yes, sir, you do have the commitment. In fact, the Department of Energy, the Fossil Energy Office, has been working with the Colstrip owners and operators. We've done two studies to date. One of those studies was to evaluate ways to improve the efficiency of the Colstrip power plant and, of course, when you improve the efficiency, you reduce emissions. So that's key. And also, the second study that we did evaluated CCS opportunity for, as you say, enhanced oil recovery and I believe that was to a southeast Montana oil field.

So yes, you have my commitment. We're happy to work with Colstrip to see what opportunities there are to keep the plant open, reduce its emissions and provide a value stream for enhanced oil recovery.

Senator DAINES. Thank you. I appreciate that.

Mrs. Lagano and Mr. Jackson, you have both have gone through the process of finding and attracting investors and securing DOE commitments. What are some of the steps that you took to secure the investment by DOE and outside partners and how might we replicate that in Montana?

Mrs. LAGANO. Yes, I'd love to start. So thank you, Senator Daines.

So in Petra Nova's case, the steps, the very important steps. First off, starting with authorizing the program. Then second, funding the program. Then competing for the funds and winning. And then, doing our homework, homework on the technology and the options. Then formulating strategic partners and those are partners that have vested interests similar to yours or maybe different than yours, but they must have a vested interest in the success of the project. And then, execution, so project execution because we know with funds comes a responsibility to spend those funds and stay within budget and keep within schedule. So those are very important steps. Each one has to be done with precision and has to be done in a way in which the goal is to turn the funds into a successful project on time and on budget.

Senator DAINES. Thank you, Mrs. Lagano.

Mr. Jackson?

Mr. JACKSON. Yes, thank you for the question.

I think, yeah, I'm going to build upon the partnership. I think the DOE, other industries, even our peers have been essential in putting together commercial projects to look at and move forward. So I think 45Q is a tremendous step that gave confidence to investors, because we deployed capital that's beyond our corporation. So that's been important. I think now it's putting these projects together. It's making it happen and put it together.

We do think technology—and we appreciate the initial question—technology on reducing cost of capture is important and will help scale this.

And again, as we've mentioned before, infrastructure.

The last comment I'll make with respect to new and different areas for CCUS, one opportunity that we found moving into this over the last year and based on our long history in enhanced oil recovery, is technical partnership.

So we actually, part of the team that I lead, opened a group that does just that, where there may be an industrial source that does

not have the capability to look at the technology around capture or sequestration and we believe it is a good business but it's also helpful for global CCUS to promote that capability beyond ourself.

Senator DAINES. Thank you.

And just one follow-up. Are there any obstacles that you encountered as you moved through this process? Perhaps lessons learned you might share for a plant that is interested in a similar investment and how might the EFFECT Act help achieve that goal?

Mr. JACKSON. I do think the technology cost needs to continue to come down. So that's a very important initial hurdle.

I think the investability of a project, meaning well understood application of 45Q tax credits across a business structure as we put together these projects, will be critical.

So as we bring more projects to the table, that will really enable this to happen.

Senator DAINES. Mrs. Lagano?

Mrs. LAGANO. Yes, and I think on the R&D front what we learn in our application, for example, in the first of a kind, large scale you would imagine you'd have to build in some margin into that design because of uncertainty, no one has done it before. We engineer it. We study it. But, you know, until it actually is put in service, then we see how it actually performs.

Once we know that, then with the next generation, the next application, perhaps we can take some of that margin away and drive the cost down that way. You know, for example, the absorber which is a 300-foot tower. It's a vessel onsite. It's the largest vessel onsite. It's a very important piece of equipment because that's where the amine, you know, extracts the carbon from the flue gas. So if you could drive that cost down 10 percent, 20 percent, that's a very important advancement such that the learning from the experience that we had, we can reduce that cost going forward of the overall capital cost. That's very meaningful.

Senator DAINES. Right. Thank you.

Chair Murkowski, Ranking Member Manchin, again, I want to thank you both for your leadership in this area and Senator Manchin, particularly, thank you for getting out in front of this issue.

It is very important, I know, for your state, for my state and for this country. Thank you.

The CHAIRMAN. Thank you, Senator Daines.

Senator Manchin, I know you are running off to another committee, but if you would like to——

Senator MANCHIN. What we are concerned about, Mrs. Lagano, is the 45Q tax.

Mrs. LAGANO. Yes.

Senator MANCHIN. Okay, 45Q tax credit, do you qualify for that?

We talked and you said there were some concerns you had. We had to make some adjustments for some—like Petra Nova is already out there and running.

Mrs. LAGANO. That's right.

Senator MANCHIN. And you are not financially viable right now if it was not for the commitment you all have made. Another company might just walk away from Petra Nova.

Mrs. LAGANO. So, and we're encouraged——

Senator MANCHIN. Financially, I mean.

Mrs. LAGANO. Yes, and as was mentioned on the panel earlier that there is a request for comments on how the 45Q tax credits can be implemented in a way that provides flexibility for operating projects such as Petra Nova and other projects for eligibility for and receipt of the credit and how that could be monetized. We are working with and providing comments on that, because it is important for us to access that.

Senator MANCHIN. Well, the deadline is 2024.

Mrs. LAGANO. Yes, it is, right, Senator.

Senator MANCHIN. And we know that is not—we are looking at extensions on that, and I think we have talked about the extension.

But if you don't qualify and don't get the 45Q tax credits, will it put you all in jeopardy at the plant?

Mrs. LAGANO. Well, it's an important net part of the economics of the plant and we expect to be able to get that, but we need to straighten out some of these administrative issues such that we can access and receive the credits.

Senator MANCHIN. And you all are working with our staffs?

Mrs. LAGANO. Yes, yes, with Treasury, the IRS and the EPA.

The CHAIRMAN. Thank you. Thank you, Senator Manchin.

Senator Hoeven.

Senator HOEVEN. Thank you, Madam Chairman.

Secretary Winberg, in North Dakota we have Red Trail Energy which is an ethanol plant that wants to capture CO_2 and put it down a hole to make it. I think they are looking primarily just at storage, not tertiary oil recovery, but to have low carbon fuel for the West Coast. So that is an example of renewable energy that wants to utilize carbon capture. Then we have Project Tundra which is an existing coal-fired plant adding back-end capture on CO_2. They want to put CO_2 down a hole actually for tertiary oil recovery, and they are partnering with oil companies to do that. Then we have Allam Cycle which wants to build a new plant to do carbon capture. In all cases we have the State of North Dakota that is putting up money to do it.

Well, let me start here. In each case we have the companies themselves and a consortium of companies putting up a lot of money to do this. They can do it technologically. We have to get the commercial viability. The companies themselves are putting up a lot of money and not even individually, actually grouping together to put up money. The State of North Dakota, through the Lignite Energy Council, is putting up money. Private sector partner, state partner. What partner is missing from that equation? If you guessed Federal Government, that is the right guess.

So we need you in these projects. Tell me which funds and how you are going to invest in these projects so we can get going, because we have been talking about carbon capture forever.

I would like to actually—and you talked about some projects that are going. It seems to me we have to do some more. How do we get that going now so we are not just talking about it this year, we are doing more of it?

Mr. WINBERG. We've had a longstanding relationship with, the Department of Energy, had a longstanding relationship with EERC.

With respect to Red Trail Energy, we have a funding opportunity notice that we released April 1st of 2019. It's titled, Regional Initiative to Accelerate CCUS Development. We typically don't advise private entities on whether or not they should bid. This is a competitive——

Senator HOEVEN. Of course.

Mr. WINBERG. ——notice and so, certainly they could bid on this and I know that EERC has a working relationship with——

Senator HOEVEN. Now which funding, which one of the funds is that, Secretary?

Mr. WINBERG. It's called the Regional Initiative to Accelerate CCUS Development.

Senator HOEVEN. Great. And that is now open and again, an open, fair, transparent, competitive bid, that is what we want.

Mr. WINBERG. Yes, sir.

Senator HOEVEN. But I just want to know we are going to get, our guys are going to get, a shot at it. And that is available now?

Mr. WINBERG. It is available. It closes on June 3rd.

Senator HOEVEN. Fantastic.

Now tell me about for the Project Tundra, the back-end capture and for a new plant. Which funds? Where are you at in the process for those?

Mr. WINBERG. There's a $30 million FOA that has closed now and so, we're in a procurement sensitive period. I think you could talk to John Harju about whether they submitted a proposal or not.

Senator HOEVEN. Right.

Mr. WINBERG. But so, there's that.

And we've also been very active with EERC on CarbonSAFE as well as the PCOR Partnership. So it's a longstanding relationship with millions of dollars that have gone into the State of North Dakota.

Senator HOEVEN. Well, that is——

Mr. WINBERG. And mostly because the State of North Dakota has been a good partner with the Department of Energy.

Senator HOEVEN. Yes. Well, and that is the key.

I just want to know that you are getting it going. It sounds like you are. I appreciate it.

But you know, we have been talking, there has been a lot of talk about this and I just think we have to do a lot more "do" on it. I am very encouraged that you are getting these things going.

John, are you—any thoughts in terms of how the process is? Is it moving along well now with DOE and the way it should be, and are we going to get to the "do" instead of just the talk?

Mr. HARJU. Yes, sir, I'm confident that we will.

Senator HOEVEN. Good, alright.

Then the other question I have for you. Again, thank you, Secretary, I appreciate it.

The other question I have for you is 48(a). We are trying to reconcile EPA regs and IRS regs when we put CO_2 down a hole for tertiary oil recovery, and we have had some challenges there. It is one thing to put CO_2 down for geologic storage and we have the regulatory regime in North Dakota to do that, not only while they are doing it, but post, when they are no longer doing it. They pay into a trust fund and then the state, ultimately after ten years,

takes responsibility. So that regime is there to handle geologic storage.

But remember, we are trying to get to commercial viability so we can create a revenue stream that really helps these companies. To do that, they have to qualify on these wells, not only with EPA in terms of the geological storage of that CO_2 as well as pushing the oil out, but then they also need to qualify for the tax credit with IRS and Treasury.

Any thoughts, I mean, so that is legislation we are trying to move. I would think anybody interested in capturing CO_2 would be all for it. But if somebody were interested in capturing CO_2 but they really still were against fossil energy, they might not get on board. So any good advice on what we can do to reconcile those regulations either legislatively or through regulatory fiat so that these companies can capture that additional revenue stream?

And if somebody else has a thought on that, I know I am a little past my time, with the indulgence of the Chair, if somebody else had a thought on that, I would sure appreciate it as well. I know Senator Gardner has immense patience, so he will be okay.

Seriously, any help on that issue which, again, is very important when we are talking about trying to get to commercial viability. It is reducing costs, but it is also increasing revenue.

Mr. WINBERG. Right, and we've had some discussion about 45Q here. The IRS is working through the rules. The quicker that happens, of course, the quicker that a number of companies at this hearing can avail themselves of the 45Q tax credit.

We've also had discussions about direct air capture. So if there is consideration about amending 45Q to allow smaller sizes for the direct air capture, that probably could be useful. I'm sure some of the panel members have other thoughts as well.

Senator HOEVEN. Any other thoughts on getting that in place?

Dr. FRIEDMANN. Yeah, two quick things.

One of them to follow up Assistant Secretary Winberg's last comment. There's a new report put out by the Rhodium Group that proposes a set of discreet policy measures to support direct air capture deployment, including amendments to 45Q. They're very clear, very straightforward and easy to access.

With respect to the question about how do we get more of this going, fundamentally? As I said earlier, really, I view this as a finance question as opposed to a cost question. And so, additional policies are valuable, and I made a handful of recommendations in my testimony.

One thing that I think is important to recognize though, especially to those who stand opposed to deployment of carbon capture and storage, you have to build a partnership where monitoring is clear, robust and transparent. If the monitoring of CO_2 storage is not clear, robust and transparent, people will have issues with that and will seek to disrupt projects.

It has been our experience over the past 18 years that engaging communities, engaging stakeholders early, is essential to get there. There's, kind of, no substitute for that. And actually, EERC has been an exceptional example of the right way to go about doing that.

And so, but I think that to recognize that if, especially, if you're going to be getting some kind of federal tax credit or something like that, if there's a public benefit that derives from this, then there needs to be representation of that to the public.

Senator HOEVEN. Right on, Doc. Well said. That is why we have invested incredible time and effort, in terms of both a legal and regulatory regime in our state, to do what you say so that it is accountable, not just at the company level, but people know the state is going to back it up, ultimately, so that it is done in an environmentally sound way. So I could not agree with you more.

Anyone else? Yes?

Mr. HARJU. Senator, while you were out, I did take a moment to applaud your leadership as our Governor.

Senator HOEVEN. Wonderful, thank you.

Mr. HARJU. And putting forward those comprehensive—and signing them into law. But if you'll recall, you were actually a sponsor through the Industrial Commission of that comprehensive body of regulatory regime for geologic storage and a real champion of what turned into a long and onerous process of gaining primacy.

Senator HOEVEN. Yes.

Mr. HARJU. In particular, with respect to the 45Q program, I think there are extensions of time which Senator Manchin alluded to a little bit. I think there are also extensions regarding eligibility which Mrs. Lagano focused on a little bit.

But also, on this notion of reporting requirements and how one certifies that storage, and I think where we're at today is it's a little bit clunky and we are pleased that IRS is seeking public comment there. But I would certainly hope that something like ISO or something like our comprehensive program in North Dakota would be an effective replacement for some of that more clunky regulatory oversight that we see today.

Senator HOEVEN. Thank you.

Again, Madam Chairman, thank you for your indulgence. I know I went over my time, but I very much appreciate it.

The CHAIRMAN. No, Senator Hoeven, this has been a very informative hearing and I think we have all gained a great deal.

In fact, all of us have gone over our time, so it must mean that we are getting good information to the questions that we have asked. So I thank you for that.

I wanted to just ask one more quick question to you, Mr. Harju.

When we were talking about partnerships and all that you are doing there with Project Tundra, you mentioned the opportunity to expand the efforts that you are focused on with other partners and looking to Alaska. Would this be through the university or how do you structure that?

Mr. HARJU. Yes, thank you for the question, Senator Murkowski.

So Secretary Winberg mentioned a regional initiative——

The CHAIRMAN. Right.

Mr. HARJU. ——solicitation that is out right now.

Thanks to Senator Hoeven's introduction to you and your introduction to some of your constituents, we're actively engaged in preparing a proposal that would broadly expand that nine state, four province region that we've been working on to include your state and what we see as some very interesting opportunities to not only

build out this infrastructure and the approaches to doing CCUS projects but also to broadly increase that geologic or geographic footprint.

Thank you.

The CHAIRMAN. Well, I look forward to that.

I think, again, there is so much that we can learn from one another. This regional approach, as you know, up North in Alaska, we have been utilizing EOR for our oil fields for decades now. And, you know, we feel that we have some good technologies in place there with the applications that we have, how we share that with others, and also how we can look to other utilizations. It was interesting to hear that we are not only looking at application, again, for purposes of enhanced oil recovery but you mentioned the prospects for cement and plastics and we are really thinking beyond today's application which, I think, is an important part of this discussion and just a reminder that this is all moving fast.

While we might be a little frustrated that we are not seeing as much coming into commercialization as quickly as we would like because of the cost, because of the learning curve, learning these, the different applications in different areas. I think there can be a frustration and then you have colleagues like Senator King who are pointing to what we know our reality is with the levels of carbon that we are seeing and what do you do? What do you do?

So there is a sense of urgency. We urge you to be more creative, more nimble, more malleable as you work to build out, what I think, are some very exciting opportunities for us.

But as you are being creative, you also need to urge us to be responsive in what role and how the government can be a better partner in all of this.

I think we recognize that we are not just there with a checkbook, but we are there to support levels of enhanced R&D. We are there to support financing opportunities through structures like the tax credits and like loan guarantees but also the whole necessity, because it truly is a necessity, for this partnering and not just partnering within the industry, not just partnering within this country, but partnering more broadly, more globally as we address what we know to be a global issue, a global problem.

I thank you for what you have shared with the Committee. You have given us a lot to focus on as we think through our initiatives. So don't consider this input that you have provided today as just a one-off and then you go off and do your thing and you don't have any more back and forth with us. The whole purpose of this is that we can continue to learn from you.

Thank you for your expertise, and thank you for sharing it with the Committee today.

With that, we stand adjourned.

[Whereupon, at 11:44 a.m. the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

U.S. Senate Committee on Energy and Natural Resources
An Examination of the Department of Energy's Carbon Capture, Utilization, and Storage Programs and to Receive Testimony on S. 1201, the Enhancing Fossil Fuel Energy Carbon Technology Act of 2019
Questions for the Record Submitted to the Honorable Steven E. Winberg

May 16, 2019

QUESTIONS FROM CHAIRMAN LISA MURKOWSKI

Q1. About 85 percent of all carbon emissions come from outside of the U.S., and demand for coal-fired power generation is growing across much of Asia. By making CCUS deployment a priority, I think the U.S. has an excellent economic opportunity to become the global supplier for these critical technologies. How do you see CCUS technology developed here in the U.S. being applied globally?

A1. Through the Department of Energy's (DOE) Carbon Capture Utilization and Storage (CCUS) research and development (R&D) activities, and in collaboration with its partners, the United States (U.S.) is the global leader in the development and deployment of CCUS technologies. U.S. industry is best positioned to determine the market conditions on how CCUS technologies developed in the United States can be applied globally.

Q2. I continue to hear positive news about the potential of carbon capture to extract value from carbon dioxide. Projects like Petra Nova, NET Power, and Project Tundra show that enhanced oil recovery is one potential use for captured carbon, but I believe we are only scratching the surface. What other potential markets are there for captured carbon, either now or in the future? How can Congress or the Administration assist with these efforts?

A2. Carbon dioxide (CO_2) has many current uses beyond enhanced oil recovery (EOR), such as the production of urea which is primarily used as a fertilizer and for carbonation in the beverage industry. Emerging and potential future uses include the conversion of CO_2 into cement, concrete, building products, chemicals, fuels, plastics, nutraceuticals and animal feed.

The Administration is focused on R&D activities that can improve the cost and performance of utilizing or converting CO_2 into these products. The 45Q tax credit provides users of carbon utilization technologies the opportunity to qualify for the credit and assists with the development of CO_2 markets and the deployment of carbon utilization technologies.

U.S. Senate Committee on Energy and Natural Resources
An Examination of the Department of Energy's Carbon Capture, Utilization, and Storage Programs and to Receive Testimony on S. 1201, the Enhancing Fossil Fuel Energy Carbon Technology Act of 2019
Questions for the Record Submitted to the Honorable Steven E. Winberg

May 16, 2019

QUESTIONS FROM RANKING MEMBER JOE MANCHIN III

Q1. In the last Congress, we took bold action to pass the 45Q tax credit which incentivizes the construction of carbon capture, utilization, and sequestration projects. Led by a bipartisan group of senators, that law represents some of the best thinking on this issue. It's my understanding the IRS is working on necessary guidance to clarify the use of this credit. In the time since its passage, there has been significant interest from industry in the tax credit, but I'm eager to see even more action and make sure it is a success.

Q1a. What impact do you anticipate the 45Q tax credit having in expanding deployment and bringing costs down?

A1a. The Bipartisan Budget Act of 2018 substantially increased and extended the 45Q tax credit, in turn increasing the applicable value of CO_2 stored in geologic formations to $50 per ton by 2024, and the applicable value of both CO_2 used for EOR operations as well as CO_2 "utilized" and permanently removed from the atmosphere to $35 per ton by 2024. DOE stakeholders have expressed interest in using this tax credit to help finance and deploy CCUS technologies. Analysis of the impact of 45Q is currently being undertaken by DOE.

Besides DOE, other groups are analyzing the potential impacts of 45Q including a working group under Stanford's Energy Modeling Forum that is evaluating the impact of the revised 45Q on CCS deployment using several different macroeconomic models. A National Petroleum Council study requested by Secretary Rick Perry will analyze the impact of various policy incentives on CCUS deployment.

Q1b. Do you think the 2024 deadline to commence construction will be sufficient?

A1b. Many stakeholders have expressed concern about the timelines to qualify and receive the credit. In order for projects to qualify for the credit, they need to already be well into the planning stages. An integrated carbon capture and storage/CO_2-EOR project will require time for feasibility and planning studies, front-end-engineering design (FEED) studies, and selection of the site, which may require collecting geological core samples,

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financing, risk assessment and permitting. All of these tasks need to be completed prior to commencing construction.

Depending on how the Internal Revenue Service (IRS) defines commencing construction, and the amount of planning a company needs to complete, it may not be possible for stakeholders to meet the 2024 deadline for commencing construction. Due to the complex nature of CCUS projects, the timeline for projects to commence construction could easily extend beyond the 2024 deadline. The exact timeline will depend on the features of a specific project.

Uncertainties regarding the requirements for recipients of the 45Q tax credit will prevent qualified facilities from meeting the statutory deadline for construction to commence prior to January 1, 2024. Other issues that concern stakeholders include, but are not limited to: transferability of the 45Q credit; tax treatment of partnerships; definition of secure geological storage; requirements for life cycle analysis for CO_2 utilization; and recapture of the credits. In response to these concerns, DOE is prepared to work with the Treasury Department as outlined in a December 13, 2018 letter from Secretary Perry to Secretary Mnuchin. The IRS recently issued a request for comments on the 45Q tax credit and is consulting DOE and other relevant agencies for guidance. The comment period ended on July 4, 2019 and 94 comments were received.

Q2. Just looking at the last five fiscal years, R&D funding for the Office of Fossil Energy and other offices at DOE has not changed to reflect the trends in the U.S. energy system or the greenhouse gas emissions associated with it. R&D programs that focus on power generation, for example, continue to receive the lion's share of funding across all Applied Energy offices while the technologies that help advance industry or transportation receive less support along the innovation pipeline. The investments in renewable energy in particular have resulted in greater efficiencies in solar and wind generation that reflect the importance of federal support for technologies. But to truly move the country toward its long-term climate goals and at the same time develop the technologies other countries will need, we need to heavily invest in CCUS and increase our support for technologies needed by sectors outside the power sector.

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Q2a. If enacted with the funding resources and programmatic direction in the EFFECT Act, do you anticipate the DOE would be able to make substantial progress on CCUS quickly?

A2a. With respect to S. 1201, the *Enhancing Fossil Fuel Energy Carbon Technology Act of 2019*, the Administration is currently reviewing this legislation and no position has been taken on this bill. S. 1201 directs the Department of Energy to support four programs focused on fossil energy R&D and carbon capture, utilization, and storage:

- A Coal and Natural Gas Technology Program to support large-scale pilot projects, demonstration projects, and the "development of technologies to improve the efficiency, effectiveness, costs, and environmental performance of coal and natural gas use."

- A Carbon Storage Validation and Testing Program to conduct research, development, and demonstration projects for carbon storage and establish a large-scale carbon sequestration demonstration program, with the possibility of transitioning to an integrated commercial storage complex.

- A Carbon Utilization Program to identify and assess novel uses for carbon, carbon capture technologies for industrial systems, and alternative uses for coal.

- A Carbon Removal Program for technologies and strategies to remove atmospheric carbon dioxide on a large scale.

As always, the Administration is ready to provide technical assistance as needed on this legislation moving forward.

Q2b. How do you see the Fossil Energy office working with other parts of the DOE to apply these technologies to help industrial users?

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A2b. The Office of Fossil Energy (FE) has a long history of expertise in CCUS. Collaboration with other program offices such as EERE and the Office of Science on these technologies will continue.

Q3. I think that developing more ways to use captured CO_2 is one of the most critical pieces we need to get carbon capture deployed more widely. There has been such wide interest in the 45Q tax credit, under which you're able to either store or use captured CO_2. Most of the utilization in the United States to date has been for EOR – something oil companies have been doing for decades and has the great benefit of adding life to our bountiful wells. But we need to be thinking outside the box and coming up with additional, novel uses for CO_2 where there's a growing market value. That's why we authorize a carbon utilization program in our bill.

Q3a. What are some of the barriers you see to commercializing CO_2 in the United States?

A3a. The barriers to commercializing carbon utilization and more specifically, CO_2 in the United States, are market dependent. For example, the use of CO_2 for enhanced oil recovery (EOR) has been well-established for several decades in the United States. However, the use of CO_2 for building materials is a much different market than EOR, and thus the barriers and market conditions will be different. In general, the cost of either capturing CO_2 or converting CO_2 into other products is a common barrier to commercialization across all industries.

Q3b. What are some of the more innovative uses for CO_2 that you've come across or are exploring that can be implemented in states like West Virginia without EOR opportunities?

A3b. DOE is exploring several different technologies that can provide innovative uses of CO_2. For example, DOE is exploring catalytic conversion of CO_2 into chemicals and polymers, mineralization into building products, and optimization of biological processes for conversion into higher value products such as nutraceuticals and animal feed. Many of these technologies do not rely on subsurface geology or specific geographic conditions and thus have potential for deployment in various states.

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Q4. The DOE created a network of seven Regional Carbon Sequestration Partnerships (RCSPs) to inventory CO_2 emission sources and sinks. These RCSPs have been operating over the last 16 years, and I served as the Chairman of the Southern States Energy Board, which leads one of those RSCPs, during my time as Governor. The DOE has also started the CarbonSAFE initiative to validate large-scale geologic storage, based on lessons learned from the RCSPs.

Q4a. In what ways do you see work being done by RCSPs and CarbonSAFE as contrasting and complementary?

A4a. The Regional Carbon Sequestration Partnerships (RCSPs) were a three-phase effort that focused on understanding the scientific and technical challenges of carbon storage at a regional level. These efforts included characterizing the sources of CO_2 and the potential geologic storage formations, conducting initial injection tests to validate the potential for storage, and finally, large-scale tests of a minimum of at least one million metric tons, which allowed different monitoring and modeling technologies to be evaluated and tested in a real-world environment.

While the RCSPs were focused on characterization, validation and testing of technologies at a smaller scale (~ one million metric tons), the CarbonSAFE effort is using the findings of the RCSPs and focusing on the storage complex (50+ million metric tons) to better understand the technical risk, uncertainty, and costs with projects at this scale.

Q5. The current DOE research program is largely focused on coal-based applications of technology, but the EFFECT Act would create a technology program focused on both coal and natural gas.

Q5a. Why is it important to ensure that carbon capture technologies are available for both coal and natural gas applications?

A5a. It is important to ensure carbon capture technologies are available for both coal and natural gas applications so they remain competitive with other energy resources.

Q5b. And can the federal investment be leveraged across both applications of the technology in a manner that helps to achieve operational successes of carbon capture technology when using either fuel?

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A5b. Federal investment can be leveraged for both coal and natural gas applications. DOE's CCUS research on carbon capture for coal-fired power plants is applicable to natural gas-fired systems. For example, technologies under development are focused on reducing the cost and improving the operation of carbon capture systems, which are common challenges regardless of fuel type or CO_2 source. Some adjustments to these technologies may be necessary to optimize the capture technology to operate for different flue gas conditions, including conditions that are found in natural gas-fired systems.

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Questions from Chairman Lisa Murkowski

Question 1: Since 2010, Congress has provided nearly $6 billion in funding for fossil energy R&D programs related to CCUS. Last year, Congress increased and expanded the tax incentives for CCUS. The EFFECT Act would build upon this success by authorizing federal support for early-stage CCUS R&D, as well as large-scale pilot projects, and commercial demonstrations. How will a more robust federal R&D program aid the deployment of CCUS technologies?

All advanced technologies that have come to market, especially advanced energy technologies, benefitted from sustained, high levels of government RD&D support. This is true for solar, wind, biofuels, batteries, shale gas, LED's and fuel cells. Perhaps unsurprisingly, advanced clean fossil technologies need similar sustained support.

Specifically, a more robust program would help accelerate market deployment. A few ideas for how the program might be expanded or augmented in critical areas:

- *New R&D lines: many of the opportunities for commercialization and rapid decarbonization lie in novel approaches, including new CO_2 capture materials, new reactors and systems to convert fossil fuel without emissions, direct-air capture technology, and novel low-C industrial processes.*
- *Large-pilots and demonstrations: many technologies have moved past the benchtop and the lab but require larger scale demonstration before markets can adopt them. A dedicated program for large-pilots and a parallel program for pre-commercial demonstration is essential for market entry and would benefit from expanded authorization and appropriations.*
- *New focus on heavy industry: Almost 15% of global emissions come from fossil fuel combustion to generate heat in heavy industry (mostly cement, steel and petrochemicals). The needs and nature of industrial systems is fundamentally different from power systems and requires more focus and dedicated research.*
- *Specific programs: The progress to date under a few key programs (e.g., supercritical CO_2 cycles, rare-earth element recovery from coal wastes) has been laudable but remains limited by current authorization and appropriations.*
- *Small businesses and underserved communities: The FE programs on serving underserved communities is far too small to serve a fraction of the good opportunities those communities seek. The same is true for small businesses, which could help create local jobs and accelerate clean energy deployment.*

For these reasons and others, the EFFECT Act would provide both a necessary course correction and an opportunity for expanded appropriations for a more robust program.

Question 2: Increasing the deployment of carbon capture in the U.S. will require a significant infrastructure investment. Currently, there are only about 5,000 miles of carbon dioxide pipelines in the country, and many thousands more will be needed to deliver captured carbon to sites for enhanced oil recovery or other use. What can Congress and the Administration do to help accelerate the expansion of this infrastructure?

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Studies suggest that small, regional networks would help serve those regions that currently lack CO_2 infrastructure, most notably Appalachia, the Midwest (from Indiana to Kansas), parts of the Rockies, and central California. Pacific Northwest National Lab estimates that a total of approximately 20,000 miles of pipeline would provide the most important infrastructure backbone for CO_2 storage and comprehensive service for those regions.

There are many things Congress could consider to support the development of infrastructure. Of course, the USE IT Act helps clarify key authorities around pipeline permitting and would apply FAST Act standards to permitting and approval. The Act has passed out of Committee and could be brought to a vote. Similarly, provisions for private activity bonds and master limited partnerships are also under Senate consideration and would help with the financing of pipeline projects. In addition to these specific actions, Congress could consider issuing block grants or matching grants for CO_2 pipelines to states or regions, possibly as part of a national infrastructure program.

Questions from Ranking Member Joe Manchin III

Question 1: In the last Congress, we took bold action to pass the 45Q tax credit which incentivizes the construction of carbon capture, utilization, and sequestration projects. Led by a bipartisan group of senators, that law represents some of the best thinking on this issue. It's my understanding the IRS is working on necessary guidance to clarify the use of this credit. In the time since its passage, there has been significant interest from industry in the tax credit, but I'm eager to see even more action and make sure it is a success.

What impact do you anticipate the 45Q tax credit having in expanding deployment and bringing costs down?

The 45Q credits have already stimulate a handful of projects and investments. We will see many projects launch soon to take advantage of the credits. However, to gain widespread deployment, particularly in the power sector, more support and incentives are needed. In order to see material cost reduction to CCS projects, additional supports are needed.

Do you think the 2024 deadline to commence construction will be sufficient?

It simply takes a long time to design and finance large capital projects like these. Even for a good CCS project, a rate limiting step is often the geological characterization, which can take years in and of itself. In order to get wide market penetration, ***Congress should extend the deadline*** *to commence construction by several years.*

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Question 2: Recently, several stories about direct air capture of carbon dioxide have caught my attention. I understand that engineers and scientists are moving quickly to identify a portfolio of technologies that remove greenhouse gases and either store them or convert them into useful products. It is obvious that forestry plays a significant and familiar role in this, but removing and using carbon in new ways shows promise for meeting and even exceeding the 2 degrees climate goal.

Can you provide us with an overview of the different types of direct air capture technologies that a robust climate and energy RD&D program should include?

Direct air capture (DAC) is one of several approaches to remove CO_2 emissions from the atmosphere. Other approaches include reforestation or creating new forests, adding carbon to agricultural soils, bioenergy + CCS, and accelerated mineral weathering. Direct air capture is noteworthy in that it is fully scalable, not limited by natural resources (e.g., land or water availability), and extremely fast. Many DAC systems today do the work of 1000's to 10,000's of trees with the footprint of one tree!

Today DAC systems are quite expensive – more than $300/ton CO_2 – and require low-carbon energy for their work. Thankfully, the technology always improves. We know the recipe for cost reduction – sustained RD&D support and policies that align market forces with technology deployment.

Today's DAC systems use physical or chemical processes to separate CO_2 from the air. They commonly use either a liquid solvent to absorb CO_2, or a solid sorbent system to adsorb CO_2. To release the CO_2 and regenerate the capture system, operators must add heat and power (practically, this should be low-carbon heat and power). Most systems deliver high quality, high concentration CO_2 (>95% purity) which is suitable for use or for storage.

How might we further incentivize this important area of research and development in the private sector?

There are two essential actions Congress could take to incentivize DAC RD&D. The first is a dedicated, sustained research program. The EFFECT Act proposes such a program, starting at the $10M dollar level. This seems appropriate and would hopefully grow as the research matures to include pilot programs, integration with CO_2 utilization, and related topics. The second is to procure CO_2 removal services using DAC + CCS to create a small initial market. This will accelerate 'learning by doing" in companies who will improve their costs and performance through in-house innovation, worker training, establishment of supply chains, etc.

Question 3: Just looking at the last five fiscal years, R&D funding for the Office of Fossil Energy and other offices at DOE has not changed to reflect the trends in the U.S. energy system or the greenhouse gas emissions associated with it. R&D programs that focus on power generation, for example, continue to receive the lion's share of funding across all Applied Energy offices while the technologies that help advance industry or transportation receive less support along the innovation pipeline. The investments in renewable energy in particular have resulted in greater efficiencies in solar and wind generation that reflect the importance of federal support for technologies. But to truly move the country toward its long-

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term climate goals and at the same time develop the technologies other countries will need, we need to heavily invest in CCUS and increase our support for technologies needed by sectors outside the power sector.

If enacted with the funding resources and programmatic direction in the EFFECT Act, do you anticipate the DOE would be able to make substantial progress on CCUS quickly?

It would certainly help. That is especially true for industrial projects (see below). Over all, the DOE can (and should) undertake large pilots, demos, and new lines of research in order to accelerate CCUS access to market. That kind of heavy investment is required to get rapid, deep decarbonization through deployment.

How do you see the Fossil Energy office working with other parts of the DOE to apply these technologies to help industrial users?

Several DOE offices are well configured to work with FE around industrial users. These include

- *the Advanced Manufacturing Office (AMO) and Bioenergy Technology Office (BETO) within EERE, which could work with FE on Bioenergy +CCS technology and projects (BECCS) in the biofuels industry, and on low-C advanced industrial manufacturing processes;*
- *the Loan Program Office (LPO), which could work with FE on identifying opportunities for demonstration projects; and*
- *the Basic Energy Sciences (BES) office within the Office of Science, which could work on novel materials and fundamental geoscience. In the past, Energy Frontier Research Centers (EFRC's) have served as excellent platforms for sustained, collaborative, interdisciplinary use-inspired research, and BES could work with FE to design and structure the R&D focus of EFRCs.*

Question 4: I think that developing more ways to use captured CO_2 is one of the most critical pieces we need to get carbon capture deployed more widely. There has been such wide interest in the 45Q tax credit, under which you're able to either store or use captured CO_2. Most of the utilization in the United States to date has been for enhanced oil recovery (EOR) – something oil companies have been doing for decades and has the great benefit of adding life to our bountiful wells. But we need to be thinking outside the box and coming up with additional, novel uses for CO_2 where there's a growing market value. That's why we authorize a carbon utilization program in our bill.

What are some of the barriers you see to commercializing CO_2 in the United States?

Two big barriers. The first is the lack of CO_2 supply that's distributed across may parts of the country. Modular CO_2 capture systems and direct-air capture can help with that. The second barrier is the mismatch between procurement standards in government and commercial enterprise and the low-C materials that are made today through CO_2 use. A concerted effort to develop and codify these standards would provide the largest impact regarding market access of new materials made from CO_2.

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What are some of the more innovative uses for CO_2 that you've come across or are exploring that can be implemented in states like West Virginia without EOR opportunities?

The most important and innovative CO_2 use is for production and curing of cement and concrete. This could be readily deployed right now across may states and would engage many small businesses in the process. FE could continue R&D on more advanced approaches. A similar line is to mineralize CO_2 as aggregate to use in building and construction. This requires first and foremost low-cost, low-carbo supplies of metal oxide, necessary to balance the CO_2 carbonation reaction

Additional innovative uses include turning CO_2 into chemicals, plastics, and durable carbon goods (such as carbon black, carbon composites, and carbon nanotubes). These could serve as a new manufacturing base for rural economies in many states. These materials require substantial energy inputs to form these new materials from CO_2, so a key research focus is efficient conversion (e.g., enabled by catalysts) and low-energy pathways to material design

Question 5: The DOE created a network of seven Regional Carbon Sequestration Partnerships (RCSPs) to inventory CO_2 emission sources and sinks. These RCSPs have been operating over the last 16 years, and I served as the Chairman of the Southern States Energy Board, which leads one of those RSCPs, during my time as Governor. The DOE has also started the CarbonSAFE initiative to validate large-scale geologic storage, based on lessons learned from the RCSPs.

In what ways do you see work being done by RCSPs and CarbonSAFE as contrasting and complementary?

I have had the pleasure to serve within the RCSPs as an investigator and to manage the RSCP's at DOE. I see the CarbonSAFE program as the natural successor to and complement to the RCPS.

- *The RSCPs were designed to help provide knowledge infrastructure for CCUS. When they began, CCUS was an unknown subject. Since then, they have successfully undertaken regional geological characterization and assessments, deployed dozens of pilots, completed several large injection projects, and laid the foundation for permitting and public acceptance. This work was essential to prepare for CCUS deployment. That work is largely completed.*
- *The CarbonSAFE program is the next logical step. These programs prepare and qualify actual sites for CO2 storage, helping industry plan and prepare for the development and launch of CO_2 capture projects. This is essential work that should be expanded.*
- *Additional work needs to be done at the local and regional level. Key tasks include helping prepare permits for CO_2 storage and CO_2 pipelines; help local lawmakers and government agencies scale up CO_2 storage efforts (including, if necessary, through additional rulemaking and legislation), and continuing public stakeholder engagement. This work could take place in either program.*

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Question 6: The current DOE research program is largely focused on coal-based applications of technology, but the EFFECT Act would create a technology program focused on both coal and natural gas.

Why is it important to ensure that carbon capture technologies are available for both coal and natural gas applications?

Today, a combination of market and technology forces shape the use and commercial viability of fuels in the power sector, and increasingly will do so in the industrial sector. This will include both the volume of coal and gas use, but also the potential for use of petcoke, liquid petroleum gases (LPGs), and ultra-heavy fuels (like bunker fuels and bitumen). In all cases, control of CO_2 emissions remains a central concern, independent of fuel type. The DOE should help prepare the nation's fossil fuel users for options in a carbon constrained world, regardless of fuel type, and must operate RD&D programs that are nimble and flexible in the face of rapid market and technology shifts.

And can the federal investment be leveraged across both applications of the technology in a manner that helps to achieve operational successes of carbon capture technology when using either fuel?

The overwhelming majority of technology and systems issues around carbon capture are fuel independent. Most CO_2 capture technology is tested on both coal and gas flue gas for certification and development, and almost all the storage and use technology is independent of the original source of CO_2. There are some specific technologies (e.g., combustion turbines, direct air capture, fluidized bed systems) that require specific RD&D programs for their progress. These should be funded to ensure continued progress.

Question from Senator Mazie K. Hirono

Question: In your testimony, you noted that "Technologies like direct air capture and CO2 mineralization, combined with turning CO2 into fuels and building materials, can potentially become a new economic engine, with distributed manufacturing hubs in rural areas and cities alike." You noted that these technologies were "represented" in the EFFECT Act (S. 1201), but are there additions to the bill that you would recommend to advance the use of captured CO2 for purposes besides enhanced oil recovery?

Yes. CO_2 conversion RD&D should be focus on both the conversion to products and on industrial synergies with existing systems (e.g., heat recovery from cement and steel production). For example, the EFFECT act calls on the creation of an industrial use R&D program. Such a program should include work both on the capture of CO_2 from industrial streams and potential integrated systems to create new industrial products from CO_2. In particular, a focus on modular CO_2 capture systems and modular CO_2 conversion systems would have high benefit and is not specifically called out in the bill as a component.

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Finally, the EFFECT Act could authorize the Office of Fossil, Energy to work with Dept. of Commerce and EPA on key issues. For example, the National Institute for Science and Technology (NIST) to help develop and promulgate performance-based standards for CO_2-based products. It could also work to support small business that develop and sell CO_2-based products to accelerate market deployment. The EFFECT Act could also direct FE to work with EPA on the development of life-cycle assessment methodologies to assess carbon footprint for these new technologies, and to improve & streamline the permitting and operational requirements for Class VI wells (which are demonstrably overburdensome for the purpose of CO_2 injection and protection of drinking water) through a science-based review.

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Question from Chairman Lisa Murkowski

Question: About 85 percent of all carbon emissions come from outside of the U.S., and demand for coal-fired power generation is growing across much of Asia. By making CCUS deployment a priority, I think the U.S. has an excellent economic opportunity to become the global supplier for these critical technologies. How do you see CCUS technology developed here in the U.S. being applied globally?

Answer: By developing and perfecting carbon capture technologies domestically, that technology can then exported around the world, bringing revenue into the US and helping to cut emissions globally. The Middle East has huge potential demand for CO2-EOR that could drive deployment of American capture technologies, as does Indonesia, Malaysia, and a number of fast growing countries in East Asia. Europe has an emissions trading system that could lead to carbon capture with sequestration across the continent. China and India don't just have sizeable carbon footprints, they also have massive capacity for carbon sequestration and utilization. CCS technologies can be applied to all major emitting countries, and doing so will be critical to addressing climate change as the 85% share of CO_2 emitted outside the US continues to rise.

The NET Power technology specifically has the advantage of releasing no air pollutants, as well as capturing >97% of its CO_2 at virtually no additional cost. This technology can thus be attractive to countries focused primarily on cheap power and air pollution. Because of its inherent carbon capture at high purity and high pressure, the CO_2 produced is too valuable to waste, and can be stored underground or utilized to make plastics, cement, and other products.

Questions from Ranking Member Joe Manchin III

Question 1: In the last Congress, we took bold action to pass the 45Q tax credit which incentivizes the construction of carbon capture, utilization, and sequestration projects. Led by a bipartisan group of senators, that law represents some of the best thinking on this issue. It's my understanding the IRS is working on necessary guidance to clarify the use of this credit. In the time since its passage, there has been significant interest from industry in the tax credit, but I'm eager to see even more action and make sure it is a success.

What impact do you anticipate the 45Q tax credit having in expanding deployment and bringing costs down?

Answer: The 45Q tax credit is a game-changing policy for the carbon capture industry, and we thank Congress for its leadership in expanding the credit last February. 45Q is the key enabling policy to accelerate deployment of carbon capture, from NET Power to retrofit post-combustion capture. By incentivizing initial projects, the cost of carbon capture technology will quickly decrease, as it progresses down its learning curve. We have already seen this happen over the last decade to the cost of solar and wind electricity, and now we've seen initial cost declines from two large-scale deployments of post-combustion amine capture first at Boundary Dam in Canada, followed by the Petra Nova project in

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Texas. Additionally, the carbon pipelines and carbon offtake infrastructure developed through 45Q projects will be re-used and built upon in future projects, further lowering the total cost of CCS.

Do you think the 2024 deadline to commence construction will be sufficient?

Answer: No, we do not believe the 2024 deadline is enough time for the carbon capture industry to achieve the necessary scale, particularly given that 15 months after draft guidance from IRS on the 45Q credit has still not been release. Carbon capture projects are complicated and capital intensive and take many years to come to fruition. Significant cost declines are very possible, but they will require multiple projects that can build on the learnings and infrastructure from completed 45Q projects. The current 45Q window from now until Jan 1 2024 is not large enough to fully realize those cost declines across the CCS industry, as there is not enough time for multiple waves of projects. An extension will be required for carbon capture to truly take off at scale, cutting costs and carbon emissions while creating jobs, just as the bipartisan sponsors of 45Q and the FUTURE Act had envisioned. NET Power is thus supportive of an extension to the commence construction deadline for 45Q.

Question 2: Just looking at the last five fiscal years, R&D funding for the Office of Fossil Energy and other offices at DOE has not changed to reflect the trends in the U.S. energy system or the greenhouse gas emissions associated with it. R&D programs that focus on power generation, for example, continue to receive the lion's share of funding across all Applied Energy offices while the technologies that help advance industry or transportation receive less support along the innovation pipeline. The investments in renewable energy in particular have resulted in greater efficiencies in solar and wind generation that reflect the importance of federal support for technologies. But to truly move the country toward its long-term climate goals and at the same time develop the technologies other countries will need, we need to heavily invest in CCUS and increase our support for technologies needed by sectors outside the power sector.

If enacted with the funding resources and programmatic direction in the EFFECT Act, do you anticipate the DOE would be able to make substantial progress on CCUS quickly?

Answer: Yes. The EFFECT act has huge potential to accelerate progress on CCUS for both the power sector and the industrial sector.

How do you see the Fossil Energy office working with other parts of the DOE to apply these technologies to help industrial users?

Answer: More flexibility in carbon capture funding from the Fossil Energy office to allow for research to span across industries - from power plants to cement plants to hydrogen production to chemical facilities – will allow faster progress to be made in developing and applying CCS technologies to the industrial sector.

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Question 3: The current DOE research program is largely focused on coal-based applications of technology, but the EFFECT Act would create a technology program focused on both coal and natural gas.

Why is it important to ensure that carbon capture technologies are available for both coal and natural gas applications?

As a natural gas carbon capture technology, NET Power exemplifies the promise of CCS on natural gas as well as coal to reduce both emissions and energy costs. Natural gas and coal both provide energy for millions of people around the world, and research on both fuels for CCS is appropriate. Additionally, many of the technologies developed for one can be adapted to the other. For example, NET Power is a natural gas capture system, but can be integrated with a commercial gasifier and a modified combustor to eliminate all the emissions from coal generation.

And can the federal investment be leveraged across both applications of the technology in a manner that helps to achieve operational successes of carbon capture technology when using either fuel?

Yes, federal investment in CCS for either coal or gas can be leveraged to benefit either fuel, as referenced above. Advancements to the Allam Cycle would benefit zero carbon use of both coal or gas. When it comes to deployment, the CO_2 infrastructure developed by initial CCS projects can be leveraged by future projects that may use coal or gas as a feedstock.

Question 4: I take a global view when thinking about the need to decarbonize. I see this as an opportunity for us to take the lead on technology development and commercialization, which we can use here at home but which we can also export to countries like China and India. This is particularly important for companies that are still building out their power grids. I understand that NET Power is demonstrating the Allam Cycle, which would have zero emissions and could potentially have lower capital costs than a combined cycle plant.

How does NET Power see its technology being applied globally?

Answer: The NET Power technology can be exported around the world, bringing revenue into the US and helping to cut emissions globally. The Middle East has huge potential demand for CO2-EOR that could drive deployment of American capture technologies, as does Indonesia, Malaysia, and a number of fast growing countries in East Asia. Europe has an emissions trading system that could lead to carbon capture with sequestration across the continent. China and India don't just have sizeable carbon footprints, they also have massive capacity for carbon sequestration and utilization. CCS technologies can be applied to all major emitting countries, and doing so will be critical to addressing climate change as the 85% share of CO_2 emitted outside the US continues to rise.

The NET Power technology specifically has the advantage of releasing no air pollutants, as well as capturing >97% of its CO_2 at virtually no additional cost. It has the potential to achieve the same capital

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cost as a combined cycle gas plant, while achieving a lower total cost of power due to byproduct revenue stream from selling CO_2, Argon, and Nitrogen.

This technology can thus be attractive to countries focused primarily on cheap power and air pollution. Because of its inherent carbon capture at high purity and high pressure, the CO_2 produced is too valuable to waste, and can be stored underground or utilized to make plastics, cement, and other products. This is clean energy that the whole world can afford, helping developing and developed countries alike reduce their emissions. Additionally, NET Power is dispatchable. It can run 24/7 as baseload, and it can ramp up and down to balance the variability of solar and wind power.

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Questions from Chairman Lisa Murkowski

Question 1: Since 2010, Congress has provided nearly $6 billion in funding for fossil energy R&D programs related to CCUS. Last year, Congress increased and expanded the tax incentives for CCUS. The EFFECT Act would build upon this success by authorizing federal support for early-stage CCUS R&D, as well as large-scale pilot projects, and commercial demonstrations. How will a more robust federal R&D program aid the deployment of CCUS technologies?

Wide-scale deployment of CCUS technology remains elusive without clear signals to the marketplace that Congressional policies will continue for the long term in support of deploying these technologies. The Congressional investment into research funding for CCUS coupled with the expanded tax incentives for CCUS deployment have been critical to moving the development of CCUS technology toward commercialization. The EFFECT Act will build upon these incentives by providing long-term authorization certainty that Congress is committed to future research funding for all stages of CCUS development. These robust policy and funding incentives send a clear signal to the marketplace that the deployment of CCUS technologies is a Congressionally supported pathway to a clean energy future.

In addition, a robust and predictable federal R&D program will allow for the development of technologies along the entire CCUS value chain, resulting in reduced costs of CCUS implementation. With robust funding for early-stage research, pilot projects, and commercial demonstrations, new transformational technologies will be developed and piloted, and those that prove most promising can be commercially deployed. The ultimate outcome of enabling these research efforts with federal policy like the EFFECT Act is a reduction of both technical and financial risk to commercial deployment of CCUS.

Question 2: Your organization is a partner in Project Tundra, a proposed CCUS project similar to NRG's Petra Nova. When completed, Project Tundra will capture 90 percent of the emissions from a coal-fired power plant and permanently store up to 3.6 million tons of carbon dioxide annually. What lessons were learned from Petra Nova's experience that will allow Project Tundra to reduce its deployment costs? What else has been learned from Petra Nova that can be applied to Project Tundra?

The success of the Petra Nova project, along with successes in the DOE Fossil Energy Program, has provided substantial reassurance to the Project Tundra team that postcombustion CO_2 capture technology can be successfully deployed at commercial scale. The DOE Fossil Energy Program, with emphasis on Petra Nova, has provided lessons learned for all phases of deployment, and most importantly to the commercial team running Project Tundra, technical and financial risks associated with a large commercial project can be managed. Lessons learned regarding financial risk are obviously critical to the Project Tundra team, but many other lessons learned from the DOE Fossil Energy Program and Petra Nova are critical, such as permitting, public acceptance, and protocols for permanent storage of CO_2. The Project Tundra team continues to scour the publicly available work products (DOE reports) to benefit from these past efforts.

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Questions from Ranking Member Joe Manchin III

Question 1: In the last Congress, we took bold action to pass the 45Q tax credit which incentivizes the construction of carbon capture, utilization, and sequestration projects. Led by a bipartisan group of senators, that law represents some of the best thinking on this issue. It's my understanding the IRS is working on necessary guidance to clarify the use of this credit. In the time since its passage, there has been significant interest from industry in the tax credit, but I'm eager to see even more action and make sure it is a success.

What impact do you anticipate the 45Q tax credit having in expanding deployment and bringing costs down?

I expect to see continued interest in utilizing the 45Q credit to kick start those projects that have been contemplated for some time and to stimulate interest in new projects. I am a firm believer that we learn by doing and that the 45Q credit will result in substantial implementation and in learning. I believe that it is reasonable to expect a 30% reduction in the deployment costs of CCUS technologies over the next 10 years as a result of the combined effects of the 45Q credit and a robust R&D program, such as that outlined in the EEFECT Act.

Do you think the 2024 deadline to commence construction will be sufficient?

I think the 2024 start date is aggressive and deserves periodic reexamination, especially as it grows closer. The lead times of projects of this nature are particularly long, both in terms of capital procurement and regulatory approvals. These lead times may prove prohibitive, especially when contemplated in concert with the current regulatory uncertainties regarding "secure geologic storage" and the liquidity/portability of any accumulated 45Q credits, which the IRS is only now soliciting comment on. In my opinion, an extension of the 2024 deadline will likely be required.

Question 2: Just looking at the last five fiscal years, R&D funding for the Office of Fossil Energy and other offices at DOE has not changed to reflect the trends in the U.S. energy system or the greenhouse gas emissions associated with it. R&D programs that focus on power generation, for example, continue to receive the lion's share of funding across all Applied Energy offices while the technologies that help advance industry or transportation receive less support along the innovation pipeline. The investments in renewable energy in particular have resulted in greater efficiencies in solar and wind generation that reflect the importance of federal support for technologies. But to truly move the country toward its long-term climate goals and at the same time develop the technologies other countries will need, we need to heavily invest in CCUS and increase our support for technologies needed by sectors outside the power sector.

If enacted with the funding resources and programmatic direction in the EFFECT Act, do you anticipate the DOE would be able to make substantial progress on CCUS quickly?

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As indicated in a previous answer, the EFFECT Act will build upon federal research funding and the 45Q tax incentives by providing long-term authorization certainty that Congress is committed to future research funding for all stages of CCUS development. I am especially pleased with the EFFECT Act's specific recognition of the Regional Carbon Sequestration Partnership (RCSP) and the CarbonSAFE efforts. These two program areas are critically important to future CCUS developments.

How do you see the Fossil Energy office working with other parts of the DOE to apply these technologies to help industrial users?

There are several program areas within DOE that could benefit from closer coordination and leadership from the Office of Fossil Energy. For example, the EERE Geothermal Program and the EERE Fuel Cell and Hydrogen Programs could benefit from the learnings within the Office of Fossil Energy. DOE has proposed ties among these programs in the past, but in my opinion, the efforts for coordination have fallen woefully short. I believe that a main driver is the lack of investment in the Office of Fossil Energy specific to these program areas. Relative to specific projects, other parts of DOE could benefit from a closer tie back to the office of Fossil Energy on CCUS technology. For instance, ADM's work with the Illinois Geological Survey and Red Trail Energy's work with the Energy & Environmental Research Center are specific examples of efforts that have dovetailed with non-Fossil industry partnering with the Fossil Energy Program.

Question 3: I think that developing more ways to use captured CO_2 is one of the most critical pieces we need to get carbon capture deployed more widely. There has been such wide interest in the 45Q tax credit, under which you're able to either store or use captured CO_2. Most of the utilization in the United States to date has been for enhanced oil recovery (EOR) – something oil companies have been doing for decades and has the great benefit of adding life to our bountiful wells. But we need to be thinking outside the box and coming up with additional, novel uses for CO_2 where there's a growing market value. That's why we authorize a carbon utilization program in our bill.

What are some of the barriers you see to commercializing CO_2 in the United States?

There are two major barriers to CO_2 utilization: capture cost and utilization scalability. The cost of capture alone renders CO_2 a valuable commodity, while most utilization concepts are not scalable enough to make a meaningful change to our overall emissions landscape. Both of these areas are ripe for innovation and deserving of Congressional support.

What are some of the more innovative uses for CO_2 that you've come across or are exploring that can be implemented in states like West Virginia without EOR opportunities?

CO_2 utilization provides a financial incentive to deploy CCUS. EOR is an obvious front runner because of the large volumes of CO_2 that can be handled and the long-term use of EOR in the United States. The Office of Fossil Energy has been examining other opportunities for CO_2 utilization. Although it is likely

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too early to pick winners, using CO_2 to grow algae and converting CO_2 to road materials, bricks, plastics, fertilizers, fuels, and rubber are emerging possibilities.

Question 4: The committee has received testimony about the valuable information gathered by virtue of Petra Nova's location on the Gulf Coast and the how that can be helpful for future projects operating in the region. With the goal of deploying CCUS across the country – not to mention globally – it's important to bear in mind that there are a variety of regional and site specific conditions, from the quality of the basic feedstock to ambient temperatures and altitude that affect the success of a project.

What value do you see in additional demonstration projects around the country where conditions may vary?

The recognition that sources, sinks, and uses for CO_2 vary across the United States and, in fact, the world is critical to the successful future of CCUS deployment. The Office of Fossil Energy's recognition of this fact has spawned the critically important RCSP and CarbonSAFE initiatives. Allowing programs like these to create additional demonstrations around the country is a must. As I'd mentioned in my testimony, regional economic forces and industrial activities largely dictate the nature of regional CO_2 emissions. I believe that we need a full slate of demonstration projects that embrace this regionality and engage those regional stakeholders that drive and fuel those regional economic engines.

Question 5: The DOE created a network of seven Regional Carbon Sequestration Partnerships (RCSPs) to inventory CO_2 emission sources and sinks. These RCSPs have been operating over the last 16 years, and I served as the Chairman of the Southern States Energy Board, which leads one of those RSCPs, during my time as Governor. The DOE has also started the CarbonSAFE initiative to validate large-scale geologic storage, based on lessons learned from the RCSPs.

You have been involved in both the Plains CO_2 Reduction Partnership and the CarbonSAFE effort. In what ways do you see work being done by RCSPs and CarbonSAFE as contrasting and complementary?

The RCSPs are designed to address the regional uncertainties and differences in sources and sinks across the United States. The RCSPs are also designed to provide best practices, promote the infrastructure for wide-scale deployment throughout these regions of the country, and build human and corporate capacity. CarbonSAFE activities, similar to other aspects of the Office of Fossil Energy CCUS Program, are designed as single-point, detailed, and deep-dive research experiments to validate specific CCUS deployments at individual, precise locations.

Question 6: The current DOE research program is largely focused on coal-based applications of technology, but the EFFECT Act would create a technology program focused on both coal and gas.

Why is it important to ensure that carbon capture technologies are available for both coal and gas applications?

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And can the federal investment be leveraged across both applications of the technology in a manner that helps to achieve operational successes of carbon capture technology when using either fuel?

Absolutely. The EFFECT Act will be critical to ensure that CCUS technologies are available for both coal and gas applications. CCUS has often been viewed as a coal solution. It is a fossil energy solution. As the natural gas boom across the United States continues to flourish, more large-scale power plants are converting to natural gas with continued emissions of CO_2. Although some technology developments for CCUS for coal are just as applicable to natural gas, there is a need to address specific natural gas issues. Kudos to the EFFECT Act for this recognition.

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Questions from Chairman Lisa Murkowski

Question 1: About 85 percent of all carbon emissions come from outside of the U.S., and demand for coal-fired power generation is growing across much of Asia. By making CCUS deployment a priority, I think the U.S. has an excellent economic opportunity to become the global supplier for these critical technologies. How do you see CCUS technology developed here in the U.S. being applied globally?

ANSWER: The good news is that United States is at the forefront of developing and using CCUS technology. Tax credits like 45Q, funding for DOE's carbon capture research programs, and industry leadership in perfecting enhanced oil recovery (EOR) utilizing carbon dioxide further enhance our global leadership. We believe the projects being developed and optimized here in the U.S. will be the proven technology that the rest of the world utilizes. One example is NetPower's electricity application, which is small and modular, can use natural gas or coal and has no carbon emissions. Occidental is also finding opportunity through a new CCUS technical service business where we are helping deploy CCUS technology and expertise as it relates to capture, transport, and secure sequestration in many projects around the world. The over forty-year experience with EOR has provided a robust data set and refined technical skills to compliment new technology developments to help advance many different types of CCUS projects.

Question 2: Since 2010, Congress has provided nearly $6 billion in funding for fossil energy R&D programs related to CCUS. Last year, Congress increased and expanded the tax incentives for CCUS. The EFFECT Act would build upon this success by authorizing federal support for early-stage CCUS R&D, as well as large-scale pilot projects, and commercial demonstrations. How will a more robust federal R&D program aid the deployment of CCUS technologies?

ANSWER: The investment that Congress has made in CCUS is beginning to catalyze real projects today. We are currently seeing an increase in project announcements directly related to the passage of 45Q. However, in order to fully realize widespread deployment of CCUS, it is important to continue to pursue technological breakthroughs in efficiency and cost reduction across a wide range of emission sources. The quickest way to ensure this happens is through sustained and robust investment in research and development, in particular, funding for the DOE's research labs. Additionally, support for large-scale projects is critical, as private financing needs support to help overcome timing and risk associated with pilot projects and provide low early stage cost of capital. Currently there is often a gap between technology R&D and large-scale pilot projects due to this lack of investment.

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Question 3: Increasing the deployment of carbon capture in the U.S. will require a significant infrastructure investment. Currently, there are only about 5,000 miles of carbon dioxide pipelines in the country, and many thousands more will be needed to deliver captured carbon to sites for enhanced oil recovery or other use. What can Congress and the Administration do to help accelerate the expansion of this infrastructure?

ANSWER: We view the CCUS proposition as three integrated parts: capture; transportation; and utilization/storage. Currently, 45Q goes a long way to help make capture projects and utilizations (like CO2 for feedstock for low carbon products – synthetic fuels and materials -- economic. Technology deployment, with the aid of 45Q, will begin to occur across a set of capture and utilization/storage cases that have access to transport. However, this deployment will be limited in terms of volume and geography. Limited access for emitters and new users of CO2 will also limit the speed of technology cost reduction that enables the creation of a diverse market place for CO2 derived products. Today, large-scale geologic storage via enhanced oil recovery is economic depending upon the price of the CO2, and geologic storage accomplished outside of EOR is appropriately incentivized by a $15/ton premium under 45Q. However, CO2 pipelines to reach these commercial sinks and a growing number of other utilizations receive no federal incentives. Building a system of long-distance pipelines designed to carry captured CO2 from/to many diverse projects can help further advance the opportunities for technology deployment and be the most significant catalyst for large scale commercial advancement CCUS. Currently, there is demand for CO2 from the EOR industry, and there will be additional demands from new industries utilizing CO2 to make products, as well as incentivized geologic sequestration. Therefore, we need pipelines to meet the demand. The challenge is building the number of capture projects needed to fill the pipeline before the 45Q tax credit expires at the end of 2023. Therefore, an extension of the tax credit will be necessary to complete the number of capture of projects required to fill the pipeline. In addition to extending the 45Q tax credit, Congress could also accelerate the expansion of CO2 pipeline infrastructure by developing low interest loans and grants to finance empty space in the pipeline until they are fully utilized.

Question 4: I continue to hear positive news about the potential of carbon capture to extract value from carbon dioxide. Projects like Petra Nova, NET Power, and Project Tundra show that enhanced oil recovery is one potential use for captured carbon, but I believe we are only scratching the surface. What other potential markets are there for captured carbon, either now or in the future? How can Congress or the Administration assist with these efforts?

ANSWER: The area of CO2 utilization beyond EOR is a fast growing and dynamic field of opportunity. New processes and products are being developed that range from building supplies like cement, to plastics, to synthetic fuels and more. Incentives like 45Q and investment in R&D will continue to make the product development pipeline more vibrant and economic as these products move toward commercialization and widespread use.

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Questions from Ranking Member Joe Manchin III

Question 1: In the last Congress, we took bold action to pass the 45Q tax credit which incentivizes the construction of carbon capture, utilization, and sequestration projects. Led by a bipartisan group of senators, that law represents some of the best thinking on this issue. It's my understanding the IRS is working on necessary guidance to clarify the use of this credit. In the time since its passage, there has been significant interest from industry in the tax credit, but I'm eager to see even more action and make sure it is a success.

What impact do you anticipate the 45Q tax credit having in expanding deployment and bringing costs down?

ANSWER: We want to thank you and the Committee for your leadership on 45Q. Because 45Q makes capture projects more economic, we expect to see additional projects announced and developed. The more projects that are developed and the more economic they become, the more likely technological breakthroughs will happen. As with wind and solar, we expect to see carbon capture costs decrease to a point where more widespread deployment of the technology will occur. The current challenge to more rapid cost reduction and technology advancement is cost of transport. To support the capture projects there is a willingness to pay for CO2 by the EOR industry, new CO2 for feedstock products, and incentivized geologic sequestration. However, the cost of transport to a set of growing demand sources remains a challenge. Support for a large scale CO2 transportation system will help enable both a reduced cost of capture and also a growing economic demand for CO2.

Do you think the 2024 deadline to commence construction will be sufficient?

ANSWER: To realize widespread deployment of CCUS, we believe that the 45Q tax credit must be extended beyond December 31, 2023, to build upon the technological advances we are currently making. As with wind and solar, it will take more time to perfect the technology and optimize its efficiency. However, we are making progress toward this goal.

Question 2: Recently, several stories about direct air capture of carbon dioxide have caught my attention. I understand that engineers and scientists are moving quickly to identify a portfolio of technologies that remove greenhouse gases and either store them or convert them into useful products. It is obvious that forestry plays a significant and familiar role in this, but removing and using carbon in new ways shows promise for meeting and even exceeding the 2 degrees climate goal.

Can you provide us with an overview of the different types of direct air capture technologies that a robust climate and energy RD&D program should include?

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ANSWER: Direct air capture (DAC) is an important and exciting CO2 capture technology. Unlike capture projects that avoid emissions, DAC actually removes CO2 from the ambient air. It is an important compliment to industrial or power sector emissions capture technologies that have been more widely known. The ability to capture CO2 directly from the air presents tremendous benefits to support large scale deployment. Modular installations allow for reduction of necessary transport costs and can be deployed to more difficult to reach utilization sinks. While DAC is advancing rapidly and shows tremendous commercial promise, continued support for both DAC and emissions capture technologies are important. Global growth and demand for energy will result in more CO2 emissions, thereby dictating the need for more capture. The need to develop the most efficient and economic capture for these facilities will be important. R&D funds should include all types of CO2 capture processes – including DAC -- and promote a set of complementary technologies that enable the most efficient and affordable CCUS system depending on unique capture and utilization attributes.

How might we further incentivize this important area of research and development in the private sector?

ANSWER: Increase R&D funding, offer grants to help pay for project development and increase incentives for DAC because it reduces ambient concentrations of CO2.

Question 3: Just looking at the last five fiscal years, R&D funding for the Office of Fossil Energy and other offices at DOE has not changed to reflect the trends in the U.S. energy system or the greenhouse gas emissions associated with it. R&D programs that focus on power generation, for example, continue to receive the lion's share of funding across all Applied Energy offices while the technologies that help advance industry or transportation receive less support along the innovation pipeline. The investments in renewable energy in particular have resulted in greater efficiencies in solar and wind generation that reflect the importance of federal support for technologies. But to truly move the country toward its long-term climate goals and at the same time develop the technologies other countries will need, we need to heavily invest in CCUS and increase our support for technologies needed by sectors outside the power sector.

If enacted with the funding resources and programmatic direction in the EFFECT Act, do you anticipate the DOE would be able to make substantial progress on CCUS quickly?

ANSWER: Yes. The EFFECT Act increases R&D funding, which is vital to making CCUS efficient and economic. Both factors are key to achieving widespread commercial deployment.

How do you see the Fossil Energy office working with other parts of the DOE to apply these technologies to help industrial users?

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ANSWER: CCUS is a great opportunity for the Office of Fossil Energy to work with other DOE offices more collaboratively to develop greater energy efficiency and more effective deployment of low carbon-energy solutions. Mixing fossil fuels production with renewables in ways that create the most economic and environmentally successful solutions is the next wave of innovation. This will provide the most direct pathway to long-term, sustainable energy solutions.

Question 4: I think that developing more ways to use captured CO_2 is one of the most critical pieces we need to get carbon capture deployed more widely. There has been such wide interest in the 45Q tax credit, under which you're able to either store or use captured CO_2. Most of the utilization in the United States to date has been for enhanced oil recovery (EOR) – something oil companies have been doing for decades and has the great benefit of adding life to our bountiful wells. But we need to be thinking outside the box and coming up with additional, novel uses for CO_2 where there's a growing market value. That's why we authorize a carbon utilization program in our bill.

What are some of the barriers you see to commercializing CO_2 in the United States?

ANSWER: The United States is in an advanced position to deploy large scale CCUS. The current 45Q support for capture and a large scale enhanced oil recovery position provides an immediate commercial CCUS model to build from and enables infrastructure and new technologies to grow. To fully develop a necessary CCUS economic system with large scale emissions abatement more diverse emissions capture and utilization technologies are critical. Great potential is being developed as technology innovators are developing products that use CO2 as feedstock. Building materials like cement, plastics, and synthetic fuels are all critical to providing a large scale willingness to pay and promote broader economic and geographic capture. However, the catalyst to enable this to occur is a national CO2 transportation system to connect broad and diverse emission sources to commercial sinks. Technology deployment, with the aid of 45Q, will begin to occur across a set of capture and utilization/storage cases that have access to transport. However, this deployment will be limited in terms of volume and geography. Limited access for emitters and new users of CO2 will also limit the speed of technology cost reduction that enables the creation of a diverse marketplace for CO2 derived products. Today, large-scale geologic storage via enhanced oil recovery is economic depending upon the price of the CO2, and geologic storage accomplished outside of EOR is properly incentivized by a $15/ton premium under 45Q. However, CO2 pipelines to reach these commercial sinks and a growing number of other utilizations receive no federal incentives. Building major CO2 pipelines that are designed to carry captured CO2 to and from many diverse projects can help further advance the opportunities for technology deployment and be the most significant catalyst for large scale commercial advancement CCUS. The pipeline financing can be supported by a willingness to pay for EOR, new CO2 as feed-stock products, or through incentivized geologic sequestration, but requires support to overcome timing uncertainty to complete many new capture projects that will fill the pipeline. Government help through low interest loans and grants to pay for empty space in the pipeline until they are filled are two actions Congress could take to accelerate the expansion of CO2 pipeline infrastructure.

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What are some of the more innovative uses for CO_2 that you've come across or are exploring that can be implemented in states like West Virginia without EOR opportunities?

ANSWER: The innovations we are most excited about are the ones using CO2 as raw material to produce products that are purchased every day throughout the U.S. and the world. Converting CO2 into common products such as tires and hoses, traditional and biodegradable plastics, clothing and other textiles, commodity and specialty chemicals, concrete and cement, and fuels is not simple nor easy, but innovators are exploring new ways and new technologies to make these products economically and sustainably. There is every reason why these products can be produced and consumed in places like West Virginia, leading to economic development, creating high-paying jobs, and resulting in more stable communities.

Question 5: The current DOE research program is largely focused on coal-based applications of technology, but the EFFECT Act would create a technology program focused on both coal and natural gas.
Why is it important to ensure that carbon capture technologies are available for both coal and natural gas applications?

ANSWER: The atmosphere and utilization products are indifferent to the origin of CO2. Developing projects that economically capture diverse sources of CO2, including those utilized from burning coal and natural gas, is key to meeting climate reduction goals as well as creating an abundant supply of CO2 to feed a growing utilization economy.

And can the federal investment be leveraged across both applications of the technology in a manner that helps to achieve operational successes of carbon capture technology when using either fuel?

ANSWER: Yes. A technology breakthrough in CO2 carbon capture will definitely benefit both coal and gas, but will also benefit the cement, steel, fertilizer, glass, and chemical industries. The primary differences between the different emission streams are the concentration of the CO2 in the emissions and other trace impurities that may be in the emissions.

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Questions from Chairman Lisa Murkowski

Question 1: About 85 percent of all carbon emissions come from outside of the U.S., and demand for coal-fired power generation is growing across much of Asia. By making CCUS deployment a priority, I think the U.S. has an excellent economic opportunity to become the global supplier for these critical technologies. How do you see CCUS technology developed here in the U.S. being applied globally?

Response: An essential objective of the Petra Nova project was to confirm that a commercial-scale carbon capture project could be constructed on time and on budget. Since achieving that objective when Petra Nova was commissioned in December 2016, the facility has hosted hundreds of interested visitors from around the world. Petra Nova also regularly receives media inquiries and requests for presentations at international conferences on topics from carbon capture to clean coal initiatives and visits. Most recently, the Department of Energy ("DOE") worked with the IEA Clean Coal Centre to host the 9th International Conference on Clean Coal Technologies in Houston where Petra Nova was highlighted with a keynote presentation and approximately 80 conference attendees visited the Petra Nova site.

The project represents an international public private partnership between American and Japanese companies with funding from (a) the U.S. Department of Energy, (b) the Japan Bank for International Cooperation (JBIC) and (c) Mizuho Bank backed by Nippon Export and Investment Insurance (NEXI). The project deploys the Kansai Mitsubishi Carbon Dioxide Recovery advanced amine-based CO_2 absorption technology, which was jointly developed by Mitsubishi Heavy Industries, LTD and The Kansai Electric Power Co., Inc.

Given the global effects of climate change and the development pipeline of coal plants in China, India and other countries, it is important to evaluate Carbon Capture Utilization and Storage (CCUS) technology for international use including potential regulatory, technical, and economic challenges in locations where construction of fossil fired generation is necessary to meet growing demand. The DOE's international partnerships, which rely both on their own R&D efforts and information shared with the DOE from projects like Petra Nova that have benefited from the DOE's involvement, present a key path to apply lessons learned on such projects on a global scale.

Question 2: Since 2010, Congress has provided nearly $6 billion in funding for fossil energy R&D programs related to CCUS. Last year, Congress increased and expanded the tax incentives for CCUS. The EFFECT Act would build upon this success by authorizing federal support for early-stage CCUS R&D, as well as large-scale pilot projects, and commercial demonstrations. How will a more robust federal R&D program aid the deployment of CCUS technologies?

Response: The DOE retaining access to R&D funding builds upon knowledge gained from the Petra Nova project, which is an important means by which to achieve meaningful cost reductions in carbon capture and fostering market interest in expanding the utilization of CCUS. For example, if there were a way to reduce the size of the 300 foot tall absorber column, which is the largest vessel on the Petra Nova site (where the amine processes the flue gas to capture CO_2), there would be a meaningful

reduction in capital costs, increasing the likelihood of future CCUS projects. Any design that is first of its kind, requires a margin of error (and budget) to accommodate uncertainties in performance. In the initial stages, each subsequent installation generates operating experience that lessens the need to maintain such margins, reducing both the initial capital investment and operating costs associated with its deployment.

Petra Nova was originally designed to process approximately 10% of the flue gas stream of the host coal unit at W.A. Parish, but due to the higher CO_2 volumes needed to support EOR operations, the project was scaled up in the development phase. As constructed, the project uses an advanced amine-based CO_2 capture system to capture 90 percent of the CO_2 emitted from a flue gas stream, equivalent to 240 Megawatts (MW) in size or approximately 40% of the flue gas stream from the host coal unit when operating at full capacity. In the process of scaling up the project, we became familiar with engineering challenges specific to commercial-scale industrial equipment operating in temperate ambient conditions. For example, this process underscored the importance of maintaining temperatures within specified tolerances for the processing of CO_2 in order to maximize capture efficiency.

The ability to apply the technology to non-baseload natural gas plants that ramp down at night and back up in the day or cycle on and off with demand would be a meaningful use of R&D funding to reflect the real-world conditions of today's fossil fueled plants dispatched to meet changing demand and firm up intermittent resources. Power plant developers want technology that is proven at least at the demonstration level before they will invest capital.

R&D is also needed to determine which technologies are most effective at the lowest possible cost – for example, if a process can be found to capture 50% rather than 90% of the CO_2 generated from a project at a fraction of the cost of the capital required for Petra Nova, it may result in an overall higher implementation and social benefit if it increases the willingness of other projects to deploy carbon capture technology.

Federal R&D can help bridge the two technical and commercial "valleys of death" commonly found in emerging technology development. There are two critical locations where a shortfall of capital often comes into play early in the development of new technology. The first is just as the technology is ready to exit the lab (technological valley of death) and the second is trying to prove the viability of a new technology at commercial scale (commercialization valley of death). The second barrier requires substantial capital and represents fundamental, structural market shortcomings that most experts believe cannot be resolved by the private sector acting on its own. This is because even in times of economic prosperity when lending standards are most flexible, the risk profiles of banks and other financial institutions are simply not positioned to back large-scale projects deploying new technologies.

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Question 3: NRG's Petra Nova project is the only operational coal-fired electric generation plant equipped with CCUS in the country. As you note in your testimony, of the project's $1 billion price tag, $190 million came from a grant from the Department of Energy. How could additional partnerships between DOE and CCUS projects help reduce the costs of deployment?

Response: The Department of Energy cost-share cash grant was critical for Petra Nova to secure debt financing for this groundbreaking technology and to enable NRG to move forward with the decision to invest private capital in the $1 billion project (which includes the Petra Nova partners' investment in the carbon capture facility and their share of the CO_2 pipeline and capital improvements at the West Ranch oilfield). It is safe to say Petra Nova would not have happened without the support of the DOE.

Carbon capture like other new technologies is expected to see significant cost reduction when it begins to be deployed at scale. Government partnerships on first of a kind installations can help build momentum for further deployment.

Questions from Ranking Member Joe Manchin III

Question 1: In the last Congress, we took bold action to pass the 45Q tax credit which incentivizes the construction of carbon capture, utilization, and sequestration projects. Led by a bipartisan group of senators, that law represents some of the best thinking on this issue. It's my understanding the IRS is working on necessary guidance to clarify the use of this credit. In the time since its passage, there has been significant interest from industry in the tax credit, but I'm eager to see even more action and make sure it is a success.

What impact do you anticipate the 45Q tax credit having in expanding deployment and bringing costs down?

Response: 45Q tax credits should enhance the economics of CCUS Projects and increase interest in carbon capture bringing more projects to the development stage as technology providers compete to bring their product to market. I would encourage members of this committee to collaborate with your colleagues at the tax-writing committees to ensure that the 45Q tax credits are implemented in a way that both recognizes the existence of an already operational facility like Petra Nova, provides flexibility in how eligibility for and receipt of the credit can be monetized, and gives investors and other financial stakeholders certainty regarding the financial impact of the incentives over a specified period.

Do you think the 2024 deadline to commence construction will be sufficient?

Response: No. For example development of the Petra Nova project began in 2009 yet construction did not commence until mid-2014, 5 years later. While we are not suggesting that it will take this long for the development of subsequent carbon capture projects, we do believe that additional time is needed for technology providers to respond to the demand for lower cost facilities. Additional

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factors that impact the decision for investment include the final guidance under 45Q by the Treasury Department and the ability and response time for developers to attract the interest of tax equity investors.

Question 2: Just looking at the last five fiscal years, R&D funding for the Office of Fossil Energy and other offices at DOE has not changed to reflect the trends in the U.S. energy system or the greenhouse gas emissions associated with it. R&D programs that focus on power generation, for example, continue to receive the lion's share of funding across all Applied Energy offices while the technologies that help advance industry or transportation receive less support along the innovation pipeline. The investments in renewable energy in particular have resulted in greater efficiencies in solar and wind generation that reflect the importance of federal support for technologies. But to truly move the country toward its long-term climate goals and at the same time develop the technologies all countries will need, we need to heavily invest in CCUS and increase our support for technologies needed by sectors outside the power sector.

If enacted with the funding resources and programmatic direction in the EFFECT Act, do you anticipate the DOE would be able to make substantial progress on CCUS quickly?

Response: NRG supports the EFFECT Act and we appreciate the committee's leadership on this issue, including your own. The DOE cost-share cash grant was critical for both NRG's decision to invest private capital as well as Petra Nova's ability to secure debt financing for its groundbreaking technology. Continued and additional partnerships with the DOE are valuable because the DOE is engaged in numerous R&D efforts on all aspects of CCUS and partnering with industry participants benefits future CCUS projects through knowledge transfer. For example, through such partnership, we hope to gain a more robust understanding of the following:

- The behavior and impact of amines on commercial-scale carbon capture equipment as well as degradation rates and its effect on carbon capture systems.
- The effects of higher operating temperatures on critical equipment to optimize equipment size, cost, and efficiency so designers can balance engineering solutions and capital constraints.
- The capture of waste CO_2 from large point-sources, which will be applicable to all sources of fossil fuels including natural gas.
- The trade-off between percent CO_2 captured versus capital investments for unproven technologies.
- The EOR performance and storage in unconventional reservoir formations and geology.

While we can't opine on the pace of CCUS progress arising from the DOE's participation, without additional funding to support R&D, advancement in CCUS technology improvements could suffer.

How do you see the Fossil Energy office working with other parts of the DOE to apply these technologies to help industrial users?

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Response: Based on inquiries that we have received regarding Petra Nova, we understand that several areas of the DOE are working on carbon capture issues – for example, studies to better understand the how amines interact with flue gas to help improve capture efficiencies and obtaining additional information on how ramping the host units (which provide flue gas) impacts the performance of carbon capture facilities. Additionally, collaboration between the Office of Fossil Energy regarding the efficient production of CO_2 and the Office of Oil and Natural Gas regarding the efficient use of CO_2 in enhanced oil recovery operations serve both national goals of reducing greenhouse gases while supporting energy independence. Just recently, the Office of Oil and Natural Gas issued Funding Opportunity Announcements to support R&D on the use of CO_2 for EOR.

Question 3: I think that developing more ways to use captured CO_2 is one of the most critical pieces we need to get carbon capture deployed more widely. There has been such wide interest in the 45Q tax credit, under which you're able to either store or use captured CO_2. Most of the utilization in the United States to date has been for enhanced oil recovery (EOR) – something oil companies have been doing for decades and has the great benefit of adding life to our bountiful wells. But we need to be thinking outside the box and coming up with additional, novel uses for CO_2 where there's a growing market value. That's why we authorize a carbon utilization program in our bill.

What are some of the barriers you see to commercializing CO_2 in the United States?

Response: For anthropogenic supplies of CO_2 from fossil power plants, the economics of carbon capture is linked to the economics and operating profile of the host power generating unit. For our industry, ideally, CCS technology should be designed with sufficient flexibility to adapt with the changing needs and demand for fossil based generation. Carbon capture technology will decrease in cost as engineering and production efficiencies improve; however, a step change in cost and performance will only come with breakthrough technological improvements.

The value of CO_2 will continue to be a major driver for commercial viability of carbon capture. As noted above, currently the commercial worth of CO_2 in large quantities is limited to EOR applications. Spawning alternative uses for CO_2 would become an enabler for carbon capture technology. The NRG COSIA Carbon XPRIZE is an incubator for these ideas. Under the Carbon XPRIZE competition, companies are vying for a $20 million global prize to demonstrate alternative and more valuable conversion of CO_2 into products through R&D efforts (including initiatives such as CO_2 to advanced materials, chemicals, and plastics). Industries that the finalists list as potentially benefitting from advancements in the use of CO_2 include: concrete, steel, aluminum, textile, batteries, ceramic, and pharmaceutical companies, among others.

As we explore new geologic formations and geographic locations suitable for EOR, development of CO_2 pipeline infrastructure could connect new buyers and sellers and in turn increase opportunities for CCUS projects reducing costs as the industry gains experience and knowledge.

Currently, there are few uses for CO_2 capable of accepting and utilizing large amounts of captured CO_2 in real-time except EOR. The development of a national pipeline infrastructure with advanced

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CO_2 storage solutions that can buffer deliveries into other, comparatively smaller markets could help. However, introduction of anthropogenic CO_2 into these smaller markets (food and beverage, refrigeration, fire suppression, etc.) necessitates understanding market saturation and the effect on industrial capture economics.

What are some of the more innovative uses for CO_2 that you've come across or are exploring that can be implemented in states like West Virginia without EOR opportunities?

Response: As noted above, NRG is a sponsor of the NRG COSIA Carbon XPRIZE competition where companies compete for a cash prize by promoting innovative uses for CO_2 across multiple industries. In the meantime, more can be done to offer additional incentives and support where otherwise key long-term point sources aren't near usable sinks (EOR, storage) to help retain critical infrastructure and energy security where alternatives are unfeasible.

Question 4: In your testimony you talked about the valuable information gathered by virtue of Petra Nova's location on the Gulf Coast and the how that can be helpful for future projects operating in the region. With the goal of deploying CCUS across the country – not to mention globally – it's important to bear in mind that there are a variety of regional and site specific conditions, from the quality of the basic feedstock to ambient temperatures and altitude that affect the success of a project.

Based on the Petra Nova experience with a project in Texas using Powder River Basin coal, can you elaborate on the value you see in additional demonstration projects around the country where conditions may vary from what you are dealing with?

Response: Carbon capture facilities must be tailored to suit the specifics of the host facility to which they are connected.

For example, the chemical composition of the flue gas must be understood in order for the carbon capture facility to efficiently capture the CO_2 while ensuring other flue gas constituents entering into the cycle can be properly addressed. At Petra Nova, several systems are designed to address NRG's WA Parish Unit 8's flue gas composition including the caustic polishing scrubber in the quencher, the reclaiming process, and the use of activated carbon to filter the amine solvent. A better understanding of the flue gas signature for Powder River Basin coal, Eastern Bituminous, Lignite, etc. would be of value, especially as it relates to the combination of back-end control systems upstream of the CCUS (for example precipitators vs. fabric filters).

Ambient conditions also play a key role because maintaining the proper temperature of the process fluids determines the efficiency of the CO_2 capture process. Given ambient conditions in the Houston, Texas area, Petra Nova uses a combination of intercoolers, plate and frame heat exchangers, shell and tube heat exchangers, and a dedicated cooling tower to maintain temperatures. This application has pushed the upper limits of industry standards. A facility in northern climates or at higher altitudes may have the opposite challenge with needs to provide heat and proper enclosures to ensure that key systems do not freeze.

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It is unlikely that any two projects will be the same given the differences in coals, equipment configuration of the host facility, and ambient conditions.

Question 5(a): The current DOE research program is largely focused on coal-based applications of technology, but the EFFECT Act would create a technology program focused on both coal and natural gas.

Why is it important to ensure that carbon capture technologies are available for both coal and natural gas applications?

Response: The science behind amine-based post combustion carbon capture systems makes it technically feasible to couple them with gas fired generating units. In 2018, there were 21.6 GW[1] of new fossil fired generating stations commissioned in the United States, 100% of them natural gas. Assuming the useful lives of new natural gas fired power plants are on the order of thirty years, it is important to create a technology program focused on natural gas based retrofit applications for carbon capture.

The proliferation of renewables and their zero marginal cost will continue to impose economic pressure on round the clock energy pricing and coal plants with high fixed costs. Highly flexible, fast-starting, fast-ramping, fast-cycling natural gas generating resources able to start-up and shutdown swiftly, efficiently, and repeatedly are complimentary to renewable build-out in the long term. This phenomenon in the power industry bolsters the need for carbon mitigation technologies to be adapted for natural gas applications.

While new construction is natural gas based, coal plants currently, and will likely continue to operate for the foreseeable future, and thus play a key role in meeting energy needs; hence, the need for continued investment in R&D and capital deployment of CCUS for both coal and natural gas fired facilities.

The economics of carbon capture for gas generation will be quite a bit more challenging than for coal. Assuming that carbon capture required the same or similar amount of capital investment to process flue gas from natural gas fired generation with half the CO_2 extraction as it does to process the flue gas from coal fired generation, the cost per ton removed of carbon would be twice as much. In addition, if the gas fired generator is operating at intermediate and peaking level capacity factors, the efficiency of removal is impacted as well.

Question 5(b): And can the federal investment be leveraged across both applications of the technology in a manner that helps to achieve operational successes of carbon capture technology when using either fuel?

Response: Yes. Advancements and efficiency improvements on coal-based CCUS technologies will be directly adaptable to natural gas flue gas streams. Fundamentally, natural gas is better suited to capture CO_2 because it contains fewer combustion products in its exhaust gas than coal. However,

[1] https://www.eia.gov/electricity/data/eia860/

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because the CO_2 concentration is half that of coal, the same capital investment yields only half the CO_2 capture which significantly challenges the economics until we achieve technological breakthroughs including monetization of the captured CO_2.

Question 6: Petra Nova is an example of how commitment to technology can lead to demonstrated results. I had the pleasure of visiting the plant in Texas just last month and I want to thank you again for your company's hospitality. Right now, Petra Nova is the only U.S. power plant currently generating electricity and capturing carbon dioxide in large quantities – about 5,200 tons per day, I understand. And part of what makes this project work is that you're using the captured CO_2 for enhanced oil recovery, and have boosted oil production over 1,000 percent. I know that you've been working with the DOE and NETL throughout this process and are finishing out your demonstration project timeline later this year.

Based on NRG's years of experience developing and operating the Petra Nova project, what are the lessons you have learned?

Response: The DOE cost-share cash grant was critical to enable NRG to move forward with the decision to invest private capital in the project as well as for Petra Nova to secure debt financing for this groundbreaking technology. Continued and additional partnerships with the DOE can be very valuable as the DOE is engaged in numerous R&D efforts on several aspects of CCUS. Part of the original Clean Coal Power Initiative grant for the Petra Nova project involved maintaining close communication with DOE. Petra Nova has shared and worked collaboratively with the government throughout the project development and operations, sharing challenges and successes. This approach enables the government to ensure these lessons are part of the body of knowledge for carbon capture to help other projects as they advance.

With any first of a kind facility – initial commissioning and the initial years of operations are critical. Typically, this is the period when design issues arise. Working along with the technology provider, we, and consequently, the DOE, learned from these experiences.

Additionally, as this technology is new, access to experienced operators was scarce. As a result, there was an operational learning curve responding to the day-to-day balancing of facility systems to meet the demand for CO_2 from the downstream oilfield. Close coordination is required between the operators of WA Parish Unit 8, the carbon capture system, the CO_2 pipeline, and the West Ranch oil field to maintain continuity and reliability of the components to manage supply and demand throughout the entire value chain.

Given that Petra Nova depends on oilfield revenues to cover the cost of debt, operations and maintenance and ultimately, return a profit, the combination of current oil pricing and production of the field present a challenge. The Petra Nova team is focused on sustaining reliable and continuous operation of the CCS facility to support the oilfield operator in maximizing the output of oilfield and associated revenues. While oil sales are the main source of revenue for the project, other commodity prices also impact the overall economics, including (a) the cost of coal as the fuel source for WA Parish Unit 8, (b) the cost of natural gas as the fuel source for the Petra Nova cogeneration facility

providing power and steam to the carbon capture facility, and (c) the price of energy in the ERCOT market which dictates the economic dispatch of Unit 8 and the revenue from excess power sales from the cogeneration facility. All of these factors must be considered in optimizing the economics of the project.

In its third year of operation, Petra Nova is capturing over 90% of the CO_2 in the processed flue gas from WA Parish's Unit 8. We attribute the success of this project to:

- **Technology Due-Diligence** – Petra Nova thoroughly researched available technologies. We selected the technology best suited for this particular application and performed extensive front-end engineering studies to fully understand the scope and complexities of executing this project.
- **Proven Demonstration Project** – Petra Nova had the benefit of a proven 25 MW demonstration project that was the centerpiece of a robust pilot program that provided the confidence to scale up to 240 MW.
- **Project Execution** - The project leveraged NRG's strong project management capabilities and proven track record of successfully implementing large scale innovative projects such as the Ivanpah Concentrated Solar Thermal Plant in Nipton, CA and finding strategic partnerships to co-share project risks and rewards.

Future project developers will need to implement commercial structures and strategic partnerships that transfers programmatic risks to the party best suited to manage them. Petra Nova creatively unlocked a complex value chain from competitive power production to enhanced oil recovery and developed commercial arrangements between producers and consumers of CO_2. Finding common ground between disparate industries (in this case, electrical generation and oil production), with differing strategic business objectives with the unified goal of planning and executing a first of a kind integrated project was critical to its success. Although this model worked for Petra Nova, other business constructs will need to be established for broader adoption.

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Question 7: What has NETL contributed to the process?

Response: National Energy Technology Laboratory's (NETL) contributions to the Petra Nova Project were numerous and impactful. It's involvement in the project was pivotal to its success in two very important ways.

1. NETL supported the upfront development of a first-of-a-kind project at a time when the risk-reward profile was most uncertain as the design, size, technology provider, construction contract, and schedule were progressing. Without its support, advancement of the project from concept through execution would have been unlikely.
2. NETL's involvement with the project enabled NRG to pursue and secure partners bringing threshold expertise, resources, and capital to the project. A DOE backed project underpinned its integrity and carried substance important to both domestic and international stakeholders.

Question from Senator Mazie K. Hirono

Question 1: What are net carbon dioxide emissions from the coal-fired unit at the Petra Nova plant with the carbon capture system, when considering the emissions of the gas-fired turbine that powers the carbon capture system and the emissions from the additional petroleum products resulting from the use of the carbon in enhanced oil recovery?

Response: Today's commercial carbon capture technologies are energy intensive providing opportunities for improvement in next generation carbon capture. Most amine-based post combustion systems take energy (power & steam) from the host unit and consume up to 30% of the plant's net output. Petra Nova is different and unique in that it has a dedicated natural gas fired cogeneration unit to provide the power and steam needed for the CCUS process. In other words, Petra Nova is not a parasitic load to NRG's WA Parish coal unit. Petra Nova's cogeneration facility is a highly efficient 78 MW unit providing approximately 50% of its power output to Petra Nova and the remainder to the ERCOT power market. Comparing the average carbon intensity of power generated in the state of Texas in 2017 (1,166lbs of CO_2produced for every MWh on the grid) to that of the Petra Nova cogeneration facility (approximately 1,000lbs of CO_2/MWeh[2]), excess power it transports to the grid is lower emitting than the average prevailing ERCOT emission rates and significantly lower than the emissions from the host coal unit (approximately 2,000 lbs. of CO_2/MWeh).

As a cogeneration unit, waste heat from the gas turbine is used to produce almost all of the project's steam demand. As a comparison, however, we have calculated that Petra Nova's equivalent power consumption is closer to 22% which represents an almost one-third improvement in energy efficiency. It is enhancements like this that are needed to improve the economics of carbon capture.

[2] https://www.eia.gov/electricity/state/texas/

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While carbon capture system captures more than 90% of the CO_2 processed flue gas, if we were to include the emissions of the natural gas power block, we are still achieving a greater than 70% net CO_2 capture rate.

Regarding the emissions from petroleum-based products; the resulting EOR from Petra Nova's captured carbon does not increase America's oil usage or carbon emissions but simply increases the amount of domestic oil production from an existing oilfield. A barrel of oil produced domestically, at a minimum, avoids mobile emissions arising from long-haul international transport and contributes to the country's energy security by decreasing reliance on foreign sources. Alternatively, oil production from the West Ranch oilfield travels via pipeline to a nearby port where it is barged to local refineries.

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May 17, 2019

The Honorable Lisa Murkowski
Chairman
The Honorable Joe Manchin
Ranking Member
U.S. Senate Committee on Energy and Natural Resources
Washington, D.C. 20510

Re: FOR THE MAY 16, 2019 RECORD

Dear Chairman Murkowski and Ranking Member Manchin:

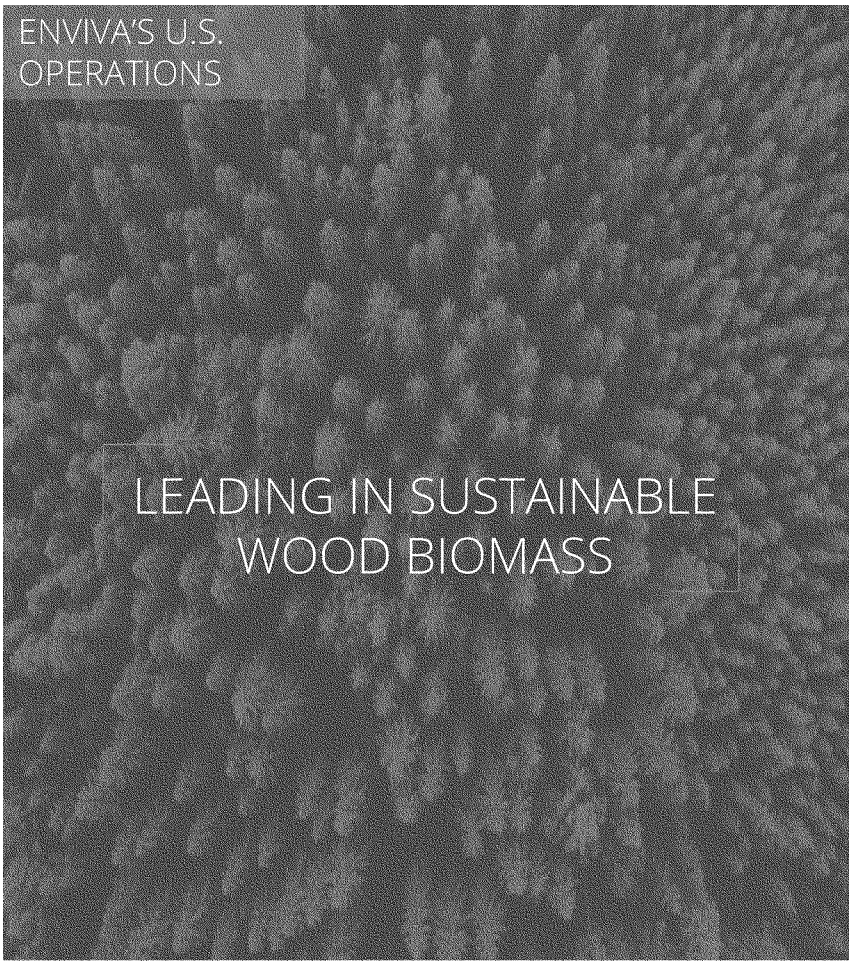
Enviva Holdings, LP ("Enviva") respectfully submits the attached materials for the May 16, 2019 "Full Committee Hearing to Examine CCUS and to Receive Testimony on Legislation" and requests that these materials be entered into the hearing record.

Enviva is the world's largest producer of wood pellets, a renewable and sustainable energy source used to generate electricity and heat. The following materials provide an overview of Enviva and how wood pellets can play a role in decreasing carbon emissions from the electricity sector:

- Fact Sheet: Enviva's U.S. Operations
- Fact Sheet: 10 Things to Know About Enviva
- Enviva's Comments on the U.S. Environmental Protection Agency's ("EPA") proposed rulemaking, Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units
- Enviva's Comments on the EPA Science Advisory Board August 29, 2018 Draft Report for Quality Review on the SAB 2014 draft Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources

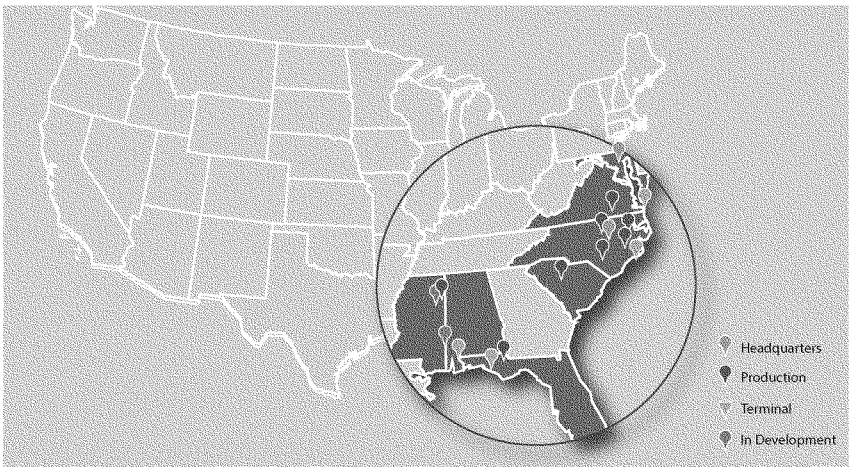
Sincerely,

Dr. Jennifer Jenkins
Vice President and Chief Sustainability Officer, Enviva



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enviva



About

Enviva **employs nearly 1,000 people**, many in rural areas in the Southeast U.S. where economic development is needed. Our experience indicates that, **for every one job created at an Enviva facility, more than two additional domestic jobs are created in the Enviva supply chain.**

Enviva **supports the broader forest products sector, which provides over 2 million U.S. jobs.**

Headquarters

Corporate Headquarters
Bethesda, MD

Operations Headquarters
Raleigh, NC

Production

Amory
Amory, MS

Ahoskie
Ahoskie, NC

Cottondale
Cottondale, FL

Hamlet
Hamlet, NC

Greenwood
Greenwood, SC

Northampton
Garysburg, NC

Sampson
Faison, NC

Southampton
Franklin, VA

Terminal Facilities

Port of Chesapeake
Portsmouth, VA

Port of Panama City
Panama City, FL

Port of Mobile
Mobile, AL

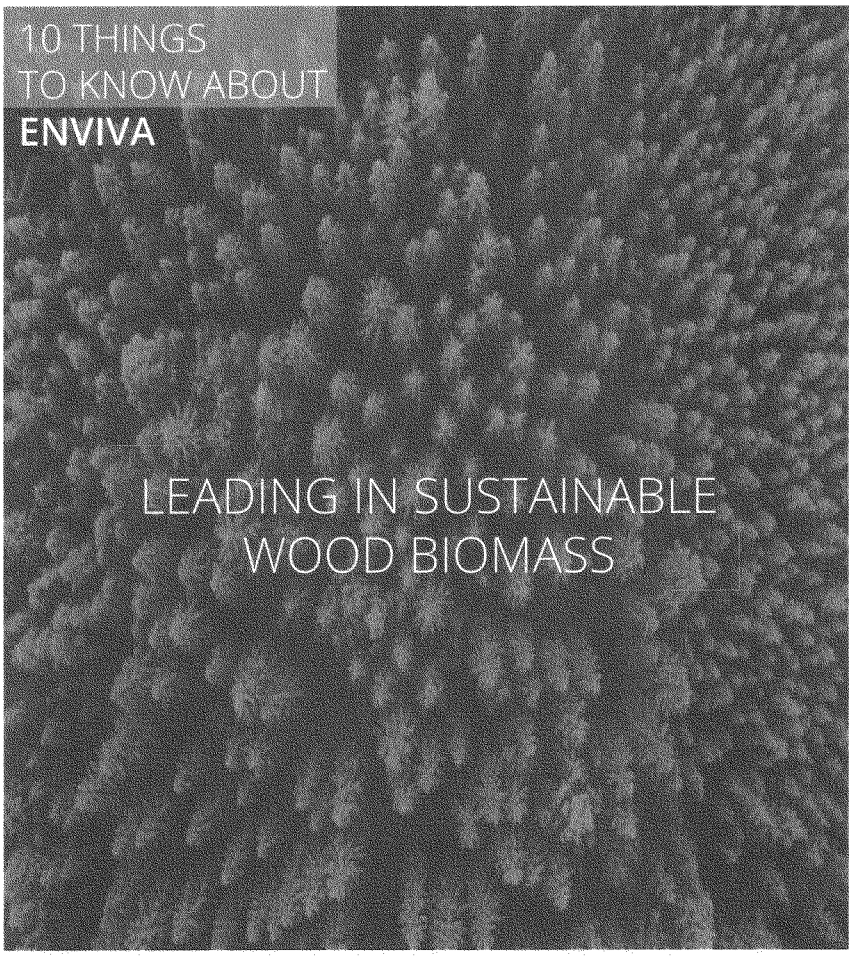
Port of Wilmington
Wilmington, NC

In Development

Lucedale
Lucedale, MS

Port of Pascagoula
Pascagoula, MS

ENVIVA'S U.S. OPERATIONS


10 THINGS
TO KNOW ABOUT
ENVIVA
LEADING IN SUSTAINABLE
WOOD BIOMASS

enviva

1. Enviva employs nearly 1,000 people, many in rural areas in the Southeast U.S. where economic development is needed. For every one job created at an Enviva facility, more than two additional domestic jobs are created in the Enviva supply chain.

2. Enviva is a leading global energy company specializing in sustainable wood biomass. We are the world's largest producer of wood pellets, which provide sustainable, low-carbon heat and power, replacing fossil fuels.

3. Founded in 2004, Enviva owns and operates seven manufacturing plants in five states: Florida, Mississippi, North Carolina, South Carolina, and Virginia. An eighth manufacturing plant in Hamlet, North Carolina, is under construction. We export our wood pellets through ports in Alabama, Florida, North Carolina, and Virginia.

4. We do more than make wood pellets—we help small towns participate in and benefit from the global economy. We connect local businesses to international markets through exports, and we help our communities preserve their environmental heritage, local character, and quality of life.

5. Enviva produces sustainable forest products in the Southeast U.S., where private forest landowners are growing 40 percent more wood than they remove every year. Enviva does not source from forests that will be converted to another land use.

6. We provide landowners with a key market for their low-grade wood—including "thinnings," limbs, tops, or crooked and knotted trees that would otherwise not get used for lumber or other higher value products. The broader forest products sector supports more than 2 million U.S. jobs.

7. Bioenergy is part of an all-in strategy to reduce carbon emissions and limit dependence on fossil fuels. As an alternative to coal, wood pellets help heat generators and power producers reduce their carbon footprint up to 85 percent on a lifecycle basis, often without undergoing major renovations to their existing structures.

8. Biomass provides a reliable, clean source of energy that complements the intermittency of wind and solar energy, ensuring a stable grid without having to rely on fossil fuel-fired backup.

9. Power generation using biomass keeps forests as forests through strong demand for forest products, including the additional value of selling low-grade fiber for bioenergy.

10. Enviva's Track & Trace® program provides transparent, publicly available data about the source of our wood, its origin in the forest or sawmill, and our procurement activities. The Enviva Forest Conservation Fund is a $5 million, 10-year initiative designed to protect and conserve tens of thousands of acres of sensitive bottomland forests in North Carolina and Virginia.



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10 THINGS TO KNOW ABOUT



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Submitted via www.regulations.gov
Docket No. EPA-HQ-OAR-2017-0355

October 31, 2018

Andrew Wheeler
Acting Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Ave NW
Washington, DC 20460

Re: Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units Proposed Rule

Dear Administrator Wheeler:

Enviva Holdings, LP ("Enviva") appreciates the opportunity to provide the U.S. Environmental Protection Agency ("EPA" or Agency) the following comments on EPA's proposed rulemaking, *Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units*.[1]

In its proposed rule, EPA "recognizes that some entities may be interested in using biomass as a compliance option for meeting the state determined emission standard" and that biomass co-firing can meet the criteria for ACE compliance.[2] Enviva appreciates EPA's recognition that the use of biomass for energy production is carbon beneficial and can help states and affected sources meet their compliance obligations.

Enviva offers the following comments to EPA to ensure that EPA provides states and affected sources the necessary guidance and certainty to encourage that biomass for energy production is used to the fullest extent possible. In particular, and as explained in more detail below, Enviva encourages EPA

[1] 83 Fed. Reg. 44,746 (August 31, 2018).
[2] *Id.* at 44,765.

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to provide to the states sufficient guidance so that states and sources have the certainty necessary to move forward with using biomass at affected sources for compliance.

I. Enviva is the World Leader in the Production of Wood Pellets for the Reduction of GHG Emissions in Utility-Scale Generation

Enviva is the world's largest producer of wood pellets, a biomass feedstock that can be co-fired with coal for utility-scale power generation. Enviva operates seven industrial-scale pellet production plants in the southeastern United States that produce more than three million metric tons of wood pellets per year. Our plants are located in states with growing forests—Virginia, North Carolina, South Carolina, Florida and Mississippi—and our headquarters is in Bethesda, Maryland. At our facilities and headquarters, Enviva directly employs more than 700 people and has created hundreds of jobs in the regions where we operate.

Woody biomass is unique in that it is a domestically produced, renewable fuel that can be used at existing coal-fired electric generating units ("EGU"). Wood pellets serve as a suitable "drop-in" alternative to coal for electricity generation because of their comparable heat content, density, and form, providing consumers access to reliable electricity that is carbon beneficial.

The use of forest-derived biomass for electricity generation can allow existing EGUs to produce reliable baseload power while meeting their GHG emission requirements.[3] The addition of wood biomass as a feedstock to the fuel stream allows for the EGU to reduce the amount of coal needed to produce the same amount of electricity. When supplementing coal with sustainably sourced biomass,[4] the additional carbon beneficial biomass fuel allows the EGU to produce the same amount of electricity with fewer GHG emissions from coal combustion. Biomass is capable of supporting baseload power generation resources, helping to maintain power system reliability in the face of increasing intermittent generation and power plant retirements.

II. EPA's Proposed Emission Guidelines Are Consistent With the Division of Federal and State Responsibilities Under Section 111(d)

EPA's proposed approach to developing greenhouse gas emission guidelines for existing EGUs gives effect to the required federal-state collaboration required by Section 111(d) of the Clean Air Act.

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[3] Enviva's perspective on the GHG benefits associated with the use of biomass fuel is based on the recognition that biogenic carbon has a different climate impact than fossil carbon – a perspective consistent with EPA's April 2018 Memorandum, *EPA's Treatment of Biogenic Carbon Dioxide (CO_2) Emissions from Stationary Sources that Use Forest Biomass for Energy Production*. The GHG emission reductions resulting from the use of sustainably sourced biomass for energy production are for reporting and accounting purposes.

[4] Enviva supports policies that recognize the carbon neutrality of sustainably sourced biomass. A framework approach for ensuring that biomass is sourced from working forests with stable or increasing carbon stocks that act as a carbon sink is discussed in Section III.C. of these comments, and was provided to the EPA Science Advisory Board ("SAB") in response to the SAB's August 29, 2018, review of the 2014 draft *Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources*. Enviva's comments to the SAB available at: https://yosemite.epa.gov/sab/sabproduct.nsf/25E8AB29D36DE7928525830D00756A0A/$File/Enviva_comment&enclosure.pdf

Under Section 111(d), EPA is required to promulgate regulations under which states must submit plans that establish a standard of performance for any existing source for a certain air pollutant "to which a standard of performance would apply if such existing source would be a new source." 42 U.S.C. §7411(d)(1). In 2015, EPA finalized new source performance standards under Section 111(b) that established standards for emissions of carbon dioxide ("CO_2") for newly constructed, modified, and reconstructed affected fossil fuel-fired electric utility generating units. 80 Fed. Reg. 64,529 (October 23, 2015). EPA's promulgation of new source performance standards for EGUs serves as the requisite predicate for EPA action under Section 111(d).

Section 111(d) sets forth a federal-state collaborative approach to the development of standards of performance for existing sources. EPA is to establish a "procedure" under which states submit plans establishing standards of performance for existing sources, reflecting the application of the best system of emission reduction ("BSER") that EPA has determined is adequately demonstrated for the source category. 42 U.S.C. § 7411(d), (a)(1). Section 111(d) leaves to the states the responsibility of "establish[ing]" the standards of performance for existing sources in the first instance. *Id.* at § 7411(d). This division of responsibility is reflected in EPA's proposed rule.

By proposing emission guidelines that inform the development, submittal, and implementation of state plans and determining a nationally applicable BSER, EPA has acted within its authority under Section 111(d). EPA's proposed emission guidelines for GHG emissions from existing EGUs provide states with the procedure by which they are to develop and submit state plans and information on the degree of emission reduction that is achievable when BSER is applied. This leaves to the states the obligation to conduct unit-specific evaluations of BSER technologies in establishing a standard of performance for a particular affected EGU. Through this collaborative approach, states are able to secure optimal emission reductions from sources that take into account a number of source-specific factors such as cost and the remaining life of the plant.

Section 111(d) assigns to the states the obligation to develop source-specific performance standards. EPA correctly recognizes in the proposal that included in this obligation is the discretion to allow sources flexibility to meet the set standard through the utilization of either BSER or non-BSER technology or strategy.

The technologies that EPA determines to be BSER are those that are "adequately demonstrated" for a source category and then determined to be the "best" while taking into account the factors of cost, nonair quality health and environmental impact and energy requirements. 42 U.S.C. § 7411(a)(1). Regardless of EPA's determination of the technology to be the "best," technologies and strategies that are not determined to be BSER may still be applicable and prudent for an individual affected source to comply with a state-developed performance standard. Past programs under Section 111(d) have recognized that non-BSER technologies and strategies may be more appropriate to meet compliance obligations at a specific affected source once source-specific characteristics are taken into account.[5] Enviva appreciates

[5] *See also* Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, 80 Fed. Reg. 64,662, 64,755 (Oct. 23, 2015) ("In addition to the BSER-related measures that affected EGUs can use to achieve the standards of performance set in section 111(d) plans, there are a variety of non-BSER measures that could also be employed (to the extent permitted under a given plan)."); Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Sewage Sludge Incineration Units 76 Fed. Reg. 15,372, 15,394 (March 21, 2011) ("A

that EPA continues to recognize the value of these non-BSER technologies and strategies and has provided explicit acknowledgement that states are free to provide sources with the flexibility to meet their compliance obligations through non-BSER technologies or strategies. 83 Fed. Reg. 44,765.

III. Enviva Supports Providing Sources With the Flexibility to Use Biomass to Meet State-Determined Performance Standards

As EPA recognizes, some states and affected sources may be interested in using biomass to reduce the emission rate of affected sources and comply with state-determined performance standards. Sustainably sourced biomass for electricity generation, and the associated emission reductions, have been clearly demonstrated. With appropriate confirmation from EPA on the carbon benefits of certain sources of biomass, and certainty on how biomass can be used to demonstrate compliance, biomass can play a significant role in assisting affected sources achieve compliance.

A. The use of biomass to achieve GHG emission reductions from electricity generation has been clearly demonstrated.

The use of woody biomass at existing EGUs to meet climate change goals has been clearly demonstrated by the experience of large scale power providers in Europe, Japan, Canada, and elsewhere. The United Kingdom and the European Union have adopted extensive regulatory programs to limit greenhouse gas emissions from the power sector. These regulatory programs encourage the use of biomass to produce power as a means for deploying renewable energy sources and achieving reduced GHG emissions. In 2017, roughly 17 million metric tons of wood pellets were used by large power providers in concert with coal-fired electricity generation or in dedicated biomass facilities to reduce GHG emissions from the power sector.[6] Co-firing of biomass with coal for electricity generation has been demonstrated at over 228 installations worldwide across a variety of boiler types.[7] A recent study reviewing the use of co-firing technology globally found that "direct co-firing is one of the most interesting and effective means of reducing GHG emissions from the coal-fired power plants."[8]

Drax, a British power provider generating 6% of the electricity consumed in Britain, operates six generation units; more than half of the total capacity is now powered by biomass. Over the course of 2016, Drax achieved an 86% reduction in CO_2-equivalent life cycle emissions relative to the benchmark for coal-fired generation in the United Kingdom under the current policy that treats biomass-fired generation as a net-zero emissions source.[9]

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source is required to meet the final emissions limits in these standards, and has the flexibility to use the control method or technology that is best suited for their individual facility.")

[6] Strauss, William. "How a low-tech renewable solid fuel is an important component of the pathway to a more decarbonized future: Wood Pellets as a Substitute for Coal in Power Generation." FutureMetrics LLC, September 16, 2017. Online at: http://www.futuremetrics.info/wp-content/uploads/2017/09/The_Benefits_of_Baseload_Low_Carbon_Electricty_Generation_by_FutureMetrics.pdf

[7] Al-Mansour, Fouad, and Jaroslaw Zuwala. "An evaluation of biomass co-firing in Europe." Biomass and Bioenergy, Volume 34, Issue 5, May 2010, pg. 620-629.

[8] Roni, Mohammad S., et al. "Biomass co-firing technology with policies, challenges, and opportunities: A global review." Renewable and Sustainable Energy Reviews 78 (2017) 1089–1101

[9] Drax Group, Sustainability Reporting, 2017. Online at: https://www.drax.com/sustainability/low-carbon/

The experience of large-scale power producers in Europe and the United Kingdom can be replicated in the United States. A technical report authored jointly by the Idaho National Laboratory and the Pacific Northwest National Laboratory found that 20% co-firing at coal plants in Alabama and Ohio would result in lifecycle emissions reductions of 16% and 14% respectively.[10]

B. Biomass co-firing or combusting biomass in dedicated boilers is an appropriate non-BSER strategy for meeting state-determined emission standards.

EPA proposes that in order for a source to demonstrate that measures taken to meet compliance obligations actually reduce the source's emission rate, the measures need to meet two criteria. First, the measure needs to be implemented at the source itself. Second, the reduced emission rate must be measurable at the source itself. 83 Fed. Reg. 44765. Using biomass for electricity generation at existing EGUs to meet state-developed performance standards can meet these two criteria.

First, using biomass to generate electricity, either through co-firing or in a dedicated boiler, is a measure implemented at the source itself. Co-firing woody biomass at existing coal-fired EGUs involves the addition of a carbon beneficial fuel blended with a reduced amount of coal to produce an equivalent amount of electricity. With minimal capital investments, existing coal-fired EGUs can be converted to dedicated biomass units. In either scenario, the use of biomass is implemented at the existing source.

Second, the reduced emission rate attributed to the use of biomass for electricity generation is measurable. The combustion of biomass itself is not carbon neutral. The carbon benefits come from the recognition there are important distinctions between carbon emissions from fossil and biogenic sources that have implications for measuring the relevant emissions from stationary sources. EPA has recognized this distinction, and declared that biogenic CO_2 emissions resulting from the combustion of biomass sourced from managed forests for energy production should be considered carbon neutral.[11] Therefore, the CO_2 emissions associated with the combustion of such biomass should not be considered in the calculation of a source's emission rate.

Because these emissions will be captured in any continuous emissions monitoring, it will be necessary for the affected source to calculate the effective emission rate based on the fuel input. In the case of an existing unit that is converted to a dedicated biomass unit that combusts biomass from a managed forest, the entire fuel content would be carbon neutral and the effective emission rate of the unit would be zero – *i.e.*, 0 lb/MWh.

In the case of an affected source that chooses to co-fire biomass from a managed forest with coal, the energy content and the relative proportions of each fuel type need to be accounted for in calculating the effective emission rate. Most affected sources already have in place an inventory system for tracking the energy content of combusted coal for use in calculations related to heat input. Where biomass co-firing is introduced, these existing systems could be expanded to track the energy content of combusted

[10] Idaho National Laboratory and Pacific Northwest National Laboratory. "Logistics, Costs, and GHG Impacts of Utility-Scale Cofiring with 20% Biomass." June 2013. Online at: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23492.pdf

[11] 83 Fed. Reg. 44,766; *see also*, EPA's Treatment of Biogenic Carbon Dioxide (CO_2) Emissions from Stationary Sources that Use Forest Biomass for Energy Production, April 2018, available at https://www.epa.gov/sites/production/files/2018-04/documents/biomass_policy_statement_2018_04_23.pdf.

biomass. This information for wood pellets is readily available. The energy content for wood pellets varies based on a number of factors, including the unique characteristics of the feedstock and the moisture content. There are strict controls and standard measurements performed by third party laboratories that certify the fuel's energy content. This information can be utilized by utilities for use in calculating the emissions attributable to the combustion of biomass. These emissions can then be credited against the measured emission rate.

C. For biomass to be used for compliance with performance standards, states and sources need guidance from EPA on what is considered a "satisfactory" state plan submittal.

As discussed above, the Clean Air Act requires each state to develop a plan for achieving emission requirements as set by EPA. These plans must be approved by EPA, so the Act requires EPA to establish via regulations a procedure that states must follow when submitting the plans to the Agency for approval. Though EPA has proposed providing states with the flexibility to determine the best manner to achieve necessary reductions, including allowing non-BSER technologies to meet performance standards, states and affected sources need clear guidance from the Agency on what will be considered a satisfactory state plan under Section 111(d)(2).

The preparation of a state plan can be a burdensome process, particularly if EPA does not provide sufficient guidance. EPA's effort to align the 40 CFR part 60 implementing regulations with the statute's current form will help provide much-needed regulatory certainty to states and operators. 40 CFR part 60.22a requires the Administrator to publish "draft emission guidelines containing information pertinent to control of the designated pollutant from designated facilities." For example, EPA's new proposed implementing regulations requiring an EPA-promulgated emission guideline to include not only the degree of emission reduction associated with each BSER, but information on the costs, nonair quality health environmental effects, and energy requirements of applying each system to designated facilities will help states make more informed decisions when developing their state plans and determining how best to apply the standard of performance to each unit. Additionally, the Agency's proposed mirroring of 40 CFR part 51 Appendix V section 2.0 completeness criteria to determine whether a state plan submission includes the minimum elements necessary for EPA to act on the submission appears to be fair, as it provides states with a submittal checklist.

While EPA notes that "[t]o the extent that a state develops a standard of performance for an affected source within its jurisdiction, the state is free to give the source flexibility to meet that standard of performance using either BSER technologies or some other non-BSER technology or strategy," the burden is on the states to take advantage of the broad authority EPA is attempting to grant in this proposal. EPA correctly notes that it is providing flexibility to the states, but states and sources also need regulatory certainty.

Additionally, for biomass to be used for compliance with state standards, EPA should provide more detailed guidance on the carbon benefits of using biomass for power generation and establish a clear approach for carbon accounting that enables sources to make informed decisions at a project's outset. As EPA has recognized, biogenic CO_2 emissions resulting from the combustion of biomass from managed

forests at stationary sources for energy production are carbon beneficial.[12] This position correctly recognizes the important distinctions between carbon emissions from fossil and biogenic sources that have implications for understanding biogenic emissions from stationary sources.

Both fossil fuels and woody biomass emit CO_2 emissions when combusted. Fossil fuels introduce CO_2 emissions into the atmosphere from carbon that was previously stored underground and separated from the climate system, whereas biogenic carbon sources release the CO_2 from organic matter. Biogenic carbon is part of an active cycle where CO_2 is absorbed by the biomass over the course of its life and then released back into the atmosphere when decomposed or burned for energy, which will again be reabsorbed by future plant growth.

In order to achieve CO_2 emission reductions, the biomass must be sourced from working forests with stable or increasing carbon stocks that act as a carbon sink.[13] In a managed forest, the harvest, growth, and regeneration are constantly occurring across the forest landscape so that when one stand is harvested, the carbon removed from that pool is being returned by new growth elsewhere in the landscape.

The key to building a credible and practical carbon accounting policy framework for working forests is to manage and evaluate the working forest as a whole and to account for land-use trends and changes in carbon stocks across the landscape.[14] These data are readily available through the United States Forest Services' Forest Inventory and Analysis ("FIA") Program.[15] Under this program, the Forest Service evaluates whether current forest management practices are sustainable in the long term. The FIA Program reports on status trends in forest area and location. EPA has already endorsed the data collected through the FIA Program through reliance on the FIA Program data in EPA's Greenhouse Gas Inventory.[16]

In considering whether a working forest has increasing carbon stock, Enviva suggests that EPA consider the landscape for a working forest to be region-specific, consistent with the approach taken in the FIA Program,[17] adjusted for consistency with forest management and markets. A region-specific approach is appropriately sized to take into account the unique landscape, forest types, and forest demands,

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[12] EPA's Treatment of Biogenic Carbon Dioxide (CO_2) Emissions from Stationary Sources that Use Forest Biomass for Energy Production, April 2018, available at https://www.epa.gov/sites/production/files/2018-04/documents/biomass_policy_statement_2018_04_23.pdf.

[13] This perspective is consistent with the SAB's recent draft review of the 2014 draft Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources, which concluded that an approach based on carbon stocks is appropriate and that the utility of a modeling approach for this application is questionable. However, because important issues related to the 2014 draft Framework remain unresolved, Enviva cannot endorse all of the SAB's draft recommendations. Enviva's comments to the SAB are available at https://yosemite.epa.gov/sab/sabproduct.nsf/25E8AB29D36DE7928525830D00756A0A/$File/Enviva_comment&enclosure.pdf.

[14] *See* A Climate Solution We Cannot Afford to Ignore: Biomass Sourced From Naturally Managed Working Forests, Roger Ballentine, Jennifer Jenkins, May 23, 2018, https://www.energycentral.com/c/ec/climate-solution-we-cannot-afford-ignore-biomass-sourced-naturally-managed.

[15] U.S. Forest Service, Forest Inventory & Analysis Program, https://www.fia.fs.fed.us/.

[16] *See* Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016, April 2018, 6-23 (stating that the underlying methodology for evaluating the net change in carbon stocks within forest land in the United States relies on data from the FIA Program), https://www.epa.gov/sites/production/files/2018-01/documents/2018_complete_report.pdf.

[17] Forest Resources of the United States, 2012: A Technical Document Supporting the Forest Service Update of the 2010 RPA Assessment, Sonja N. Oswalt, W. Brad Smith, Patrick D. Miles, and Scott A. Pugh, at 4, https://www.srs.fs.usda.gov/pubs/gtr/gtr_wo091.pdf.

while still providing a broad enough perspective on carbon emissions to capture a true account of the net carbon stock.[18]

By focusing on working forests, and by directly incorporating the policy guidance it articulated in its April statement in this new rule, EPA can enable the use of biomass from sources that have stable or increasing carbon stocks, provide clear incentives for sound and sustainable forest management, and can make tangible reductions in CO_2 from electricity generation.

D. States have the authority under Section 111(d) to allow for averaging and trading as compliance mechanisms.

Enviva appreciates EPA's recognition that averaging and trading can provide states and sources with significant flexibilities in reducing emissions. Enviva encourages EPA to expressly recognize that states can allow for averaging and trading in any final rule. Allowing for these flexibilities is both consistent with the allocation of authorities under Section 111(d) and consistent with EPA's intention to encourage meaningful reductions in GHG emissions through cost-effective measures.

The authority to allow for trading and averaging is encompassed in the state's authority and obligation to develop its state plan. By recognizing that states have the authority to allow for trading and averaging, EPA is not being inconsistent with its proposed interpretation of the BSER as limited to measures that apply at an individual affected source.

In contrast to other Clean Air Act programs, Section 111(d) is a federal-state collaboration in reducing emissions from existing sources where it is incumbent on the state to determine the emission reduction obligations and the framework by which affected sources will meet these obligations. The state is to develop source-specific performance standards achievable through the application of BSER technologies. However, as EPA recognizes, "the state is free to give the source flexibility to meet that standard of performance." 83 Fed. Reg. 44765. EPA expressly recognizes that the state can allow for the source to use non-BSER technologies. *Id.* Allowing trading and averaging is consistent with allowing states and sources to determine the optimal approach for complying with the emission standard.

The fact that the statute requires states to take into account the remaining useful life of the facility does not change this result. Once the state develops the source-specific performance standard, the affected source must evaluate the most appropriate way to comply with the standard. Even though the state's development of the performance standard is source-specific, the state's consideration is limited to the application of BSER technologies and directly relevant source-specific information such as cost. In contrast, when the affected source is developing its compliance plan, its considerations can and likely will be broader to include shareholder perspective, business opportunities, and possibly other compliance obligations within the company. Based on this more comprehensive evaluation, the affected source may

[18] The SAB also recognized the benefits of a landscape/regional analysis instead of a stand level review for this type of application in its recent draft recommendations. *See* Enviva Comments, available at: https://yosemite.epa.gov/sab/sabproduct.nsf/25E8AB29D36DE79285258 30D00756A0A/$File/Enviva_comment&enclosure.pdf.

make a decision not to implement BSER technologies in favor of non-BSER technologies either at the source or through trading at another affected source.

Biomass as a mechanism for compliance highlights the importance of allowing states flexibility through averaging and trading. As EPA recognizes, the use of biomass for compliance may be economically attractive for certain affected sources. Enviva agrees and believes that biomass has a significant role to play in supporting compliance with state-determined performance standards. However, the incorporation of biomass as a fuel at existing units can, in certain instances, be more costly than traditional compliance mechanisms and may require adjustments and tuning of the existing source. As a result, and because in some instances there are significant economies of scale associated with these adjustments, biomass may present an economical compliance option at levels that are above and beyond the emission reductions a single source needs for compliance. Allowing for the use of averaging and trading allows sources to invest in the use of biomass, and capture any over compliance through trading and averaging mechanisms at other affected sources.[19]

Enviva recognizes EPA's concerns that trading programs can be complex to develop, implement, and enforce. However, Enviva suggests that the use of trading programs to improve air quality through cost effective measures has a long history of success in the United States. Both state and federal trading programs provide models by which states individually or collectively can implement trading (or simple averaging across affected sources) programs that achieve transparent and verifiable reductions.

Enviva appreciates EPA's attention to this matter and encourages EPA to provide the direction to allow for states and sources to make use of averaging and trading.

IV. EPA Should Ensure That the New Source Review Program Does not Prevent Affected Sources From Considering Technologies and Strategies for Reducing GHG Emissions

As EPA recognizes, the New Source Review ("NSR") program has the potential to apply to affected sources that are making a physical or operational change to reduce GHG emissions and meet state-determined performance standards. 83 Fed. Reg. 44,775. The lack of certainty around when NSR applies creates substantial burdens and obstacles for operators of stationary sources. In some situations, operators undertaking a project intended to reduce emissions may need to expend significant resources to conduct analyses to evaluate applicability of NSR. In other situations, sources may be discouraged from undertaking projects necessary for preventative maintenance or for improved energy efficiency out of concern for triggering NSR. Enviva appreciates EPA's recognition that the interaction between NSR and the Proposed Rule could interfere with an affected source's compliance.

In the proposal, EPA is considering amending the NSR regulations to include an hourly emissions increase test for EGUs. Enviva supports this proposal and believes that it will provide clarity in the applicability of NSR and will reduce impediments to affected sources complying with state-determined performance standards. Although Enviva does not think that the use of biomass at an existing EGU would

[19] EPA is considering expanding averaging and trading programs to include non-affected EGUs within a facility in the limited case when they represent new non-emitting capacity, such as integrated solar. Enviva supports this expansion. The addition of a new dedicated biomass boiler would also be consistent with this application. By allowing these new sources to be included in compliance trading and averaging, EPA is encouraging the use of this domestic renewable fuel for compliance.

trigger NSR, the current annual test creates uncertainty. Enviva believes that the proposed revisions would help provide certainty to affected sources considering using biomass as a compliance strategy that NSR will not be triggered.

Biomass offers affected sources a flexible means for reducing CO_2 emissions and complying with any state-determined performance standard. Depending on the desired emission reductions, affected sources could choose to co-fire biomass with coal or they could choose to convert an existing EGU to a dedicated biomass unit. Although each affected source would need to evaluate the unique characteristics of its facility when considering using biomass, with either a co-firing or complete conversion, in general, sources can expect to make minor physical changes with minimal capital investment. As a general guideline in the industry, co-firing biomass at 5% or less requires no physical changes to the EGU. This can be accomplished either through direct injection of biomass into either the furnace or downstream of the mills or through co-milling of biomass and coal.[20] Processed biomass can be mixed with coal just before entering the pulverizer. There is no need for specialized burners or "any fundamental change in the conventional fuel delivery system."[21]

As recognized by EPA, using biomass harvested from managed forests is considered carbon neutral. In addition to reducing carbon emissions, co-firing with woody biomass reduces emissions of conventional pollutants. On an energy content basis, woody biomass has significantly lower levels of sulfur, nitrogen, ash, and mercury than coal. Therefore, the higher percentage of woody biomass utilized, the fewer emissions of conventional pollutants. Due to differences in the fuel type, an existing unit will likely need to undergo a short tuning or rebalancing period in order to optimize the burn rate and achieve these emission reductions.[22] EPA should clarify that emissions during the tuning period are not counted for purposes of either the hourly or the annual NSR test.

V. Biomass for Energy Production Promotes Forest Health and Forest Carbon Stocks

Domestic biomass for energy is sourced from same forest products landscape that already exists to support a number of substantially larger commercial industries, such as saw timber, construction materials, and commercial packaging. However, biomass used for energy feedstocks does not compete for the same feedstock. Instead, biomass used for energy generation is sourced from the lowest value byproducts in the commercial forestry supply chain – materials that are otherwise unusable or underutilized. As such, the expansion of biomass energy markets can provide important markets for these materials that would otherwise be left in the forest to decay or be burned on-site.

On public lands that are increasingly prone to devastating wildfires, converting the byproducts of forest restoration efforts can be a critical component of sustainable forestry. Clearing forests of small-diameter tops, limbs and other forest harvest residues, as well as forest restoration materials, promotes forest health and reduces risks of catastrophic fires. The recent fires in California are case studies in how

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[20] *See* Utility Biomass Use: Turning Over a New Leaf, Una Nowling, Power Magazine, May 1, 2014, https://www.powermag.com/utility-biomass-use-turning-over-a-new-leaf/?printmode=1

[21] Amirabedin, E. and D. McIlveen-Wright. "A Feasibility Study of Co-Firing Biomass in the Thermal Power Plant at Soma in order to Reduce Emissions: an Exergy Approach." *Int. J. Enivron. Res.*, 7(1): 139-154, Winter 2013.

[22] *See* Utility Biomass Use: Turning Over a New Leaf, Una Nowling, Power Magazine, May 1, 2014, https://www.powermag.com/utility-biomass-use-turning-over-a-new-leaf/?printmode=1

quickly the fires can spread with considerable forest debris.[23] Leaving untouched lower-value wood such as low-grade fiber, limbs, and industry byproduct ignores the lifecycle sequestration benefits of the wood. Because these materials at one point aided in sequestering carbon, they can be converted to energy with a low lifecycle emissions footprint.

Expanding markets for biomass used for energy production can also promote larger and healthier forests. One of the strongest drivers of deforestation on privately owned lands is conversion for alternate use, such as agriculture or commercial development. The emergence of additional markets provides further incentive to landowners to keep their forests replanted and sustainably managed. A large body of research demonstrates that biomass energy markets lead to more forests and healthier forests overall.

From the early 1950s to the late 1990s, demand for softwood forest products almost doubled while population growth and commercial development spiked rapidly, yet during this same time period carbon stocks remained constant.[24] In the South specifically, overall timber demand increased by 57% and softwood timber demand increased by 98% between 1953 and 2015. During this same time, forest inventory increased by 108% from 142 to 296 billion cubic feet.[25]

Further, a recent study from the U.S. Forest Service Southern Research Station found that an increase in demand specifically for bioenergy would result in an increase in both forest inventory and forested timberland area in the South.[26] The United States Department of Agriculture has also recognized the many benefits of the biomass industry, which include increasing forested area, reducing greenhouse gas emissions, and improving U.S. forest management practices.[27] Researchers from Duke University and North Carolina State University also found that increased demand for wood pellets elicits a positive forest market response, resulting in increased forest area and annual gains in forest carbon.[28] Additionally, both the International Energy Agency and the International Panel on Climate Change agree that biomass production can lead to both sustainable forest management and increased carbon storage.[29]

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[23] Page-Dumroese, Deborah S., et al. "Methods to reduce forest residue volume after timber harvesting and produce black carbon." *Scientifica* 2017 (2017), http://downloads.hindawi.com/journals/scientifica/2017/2745764.pdf.

[24] Miner, Reid A., et al. "Forest carbon accounting considerations in US bioenergy policy." *Journal of Forestry* 112.6 (2014): 591-606, https://www.fs.usda.gov/treesearch/pubs/download/48712.pdf.

[25] Jefferies, Hannah M, and Tracy Leslie. *Historical Perspectives on the Relationship between Demand and Forest Productivity in the South*. Forest2Market Inc., 26 July 2017, www.forest2market.com/hubfs/2016_Website/Documents/20170726_Forest2Market_Historical_Perspective_US_South.pdf.

[26] Abt, Karen Lee, et al. "Effect of policies on pellet production and forests in the US South." *USDA Forest Service Southern Research Station, Asheville, NC, USA* (2014), https://www.draxbiomass.com/wp-content/uploads/2017/01/USDA2c-Effect-of-Policies-on-Pellet-Production-and-Forests-in-the-U.S.-South-December-2014.comp_.pdf.

[27] Vilsack, Thomas J. (former US Secretary of Agriculture). Received by Amber Rudd (former UK Secretary of State for Energy and Climate Change), 28 March 2016.

[28] Galik, Christopher S., and Robert C. Abt. "Sustainability guidelines and forest market response: an assessment of European Union pellet demand in the southeastern United States." *Gcb Bioenergy* 8.3 (2015): 658-669, https://onlinelibrary.wiley.com/doi/pdf/10.1111/gcbb.12273.

[29] Miner, Reid A., et al., *See supra note 2.*

Despite population growth and increased urban development, forest inventory continues to increase each year. In fact, standing forest inventory in the U.S. South has grown by over 100% since the 1950s.[30] Over the last 15 years, during which time biomass for energy demand appeared in the marketplace, forest inventory in the U.S. South has increased by almost 1.2 billion tons.[31] As the acreage and inventory in U.S. forestland increase, so do the carbon stocks in those forests. These trends demonstrate that biomass is a sustainable energy source that can help support forest landowners and forest health.

VI. Conclusion

Biomass provides existing EGUs an attractive option for continuing operations at existing facilities and meeting the compliance obligations of any state-determined performance standard. Enviva appreciates EPA's recognition of the role that biomass can play and encourages EPA to continue to provide clear direction that supports states and sources to rely on biomass for compliance.

As the world's largest producer of wood pellets, Enviva appreciates the opportunity to comment on the proposed rule. If you have any questions or would like to discuss, please do not hesitate to contact Sasha Mackler at Sasha.Mackler@EnvivaBiomass.com or (240) 800-5703.

ENVIVA HOLDINGS, LP

By Enviva Holdings GP, LLC,
as its sole general partner

By_____
Thomas Meth
Executive Vice President, Sales and Marketing

[30] Jefferies, Hannah M. and Tracy Leslie, *See supra note 3.*
[31] Stewart, P. "*Wood supply market trends in the US South: 1995–2015.*" Forest2Market, Inc. Report Prepared for the National Alliance of Forest Owners, 19 November 2015. http://www.theusipa.org/Documents/USSouthWoodSupplyTrends.pdf.



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DATE: September 19, 2018

TO: Thomas Carpenter, DFO, United States Environmental Protection Agency (sent via email to carpenter.thomas@epa.gov)

FROM: Jennifer Jenkins, Ph.D.
Vice President and Chief Sustainability Officer, Enviva

SUBJECT: Comments on the August 29, 2018 draft report for quality review from the EPA Science Advisory Board (SAB) on the SAB's review of the 2014 draft *Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources*

Dear. Mr. Carpenter:

Thank you for the opportunity to provide comments on the August 29, 2018 draft report for quality review from the EPA Science Advisory Board (SAB) on the SAB's review of the 2014 draft *Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources*.

Enviva Holdings, LP is the world's largest producer of wood pellets, a renewable and sustainable energy source used to generate electricity and heat. Through its subsidiaries, Enviva Holdings, LP owns and operates wood pellet processing plants and deep-water export terminals in the Southeastern United States. While we produce our pellets using wood from the Southeast US, we export our product primarily to power plants and CHP facilities in the United Kingdom and Europe, where our customers typically use them to replace coal.

We believe that climate change is one of the biggest problems that we face as a society today, and we understand that the transition to a renewable energy economy is absolutely critical to the future of the planet. While its contribution today is small, policymakers around the world have concluded that a transition toward biomass and away from coal – given its ability to solve short-term intermittency, to utilize existing infrastructure, and to handle thermal loads – must be a key part of our transition away from fossil fuels.

Government policies are important for driving decarbonization in the energy sector; equally important is the growing corporate commitment to and demand for clean energy. Both public policy and corporate best practices for consuming and tracking renewable energy use require an accepted and workable carbon accounting solution for forest biomass energy. We do not think that a legitimate rule is to simply say that "all forest biomass is carbon neutral." At the same time, however, a carbon accounting solution

must be scientifically sound and based on the carbon benefits provided by sustainable forestry, *and* it must provide a workable and predictable basis upon which a potential user can make the investments necessary to convert from fossil fuel, knowing that a reliable supply of appropriate biomass will be available to fulfill that transition.

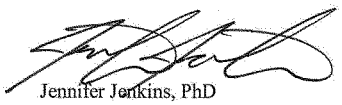
In the best interests of the climate, our goal for forest biomass should be to craft an accounting approach that: 1) discourages the conversion of forests to non-forest uses; 2) provides incentives for the growth – and not depletion – of forests; *and* 3) encourages the conversion away from fossil fuels. Together with my colleague Roger Ballentine, we laid out a framework for such an approach in our May 2018 paper (attached), entitled "A Climate Solution We Cannot Afford to Ignore: Biomass Sourced from Privately Managed Working Forests." https://www.energycentral.com/c/ec/climate-solution-we-cannot-afford-ignore-biomass-sourced-naturally-managed

We agree with the SAB's conclusion that an approach based on carbon stocks is appropriate for this purpose, and that such an analysis must be conducted on a landscape/regional basis and not at the stand level. We are pleased to see that the SAB has strongly questioned the utility of a modeling approach for this policymaking application. The market needs rules by which a consumer of forest biomass can prospectively identify adequate supply that will meet the zero carbon energy objectives that a growing number of energy consumers demand. Modeling approaches, and approaches that rely on a retroactive evaluation of the carbon value of each harvest of biomass, will not meet these needs. In particular, it is not practical or necessary to estimate some future scenario when evaluating stack emissions; instead, as we explain in our paper we can look at the landscape "balance" at the time of harvest.

There are important issues that remain unresolved, of course, and until these details are finalized we cannot endorse all of the SAB's recommendations. These outstanding issues can and should be resolved by stakeholders working together in order to enable a working market for forest biomass that will allow for fossil fuel substitution with net-zero carbon fuel while also incentivizing net forest growth.

We appreciate the SAB's work in moving this important dialogue forward, and we welcome the opportunity to contribute meaningfully and collaboratively to the regulatory development process that will undoubtedly follow.

Respectfully submitted,



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http://www.theenergycollective.com/rogerballentine/2433941/a-climate-solution-we-cannot-afford-to-ignore-biomass-sourced-from-naturally-managed-working-forests

A Climate Solution We Cannot Afford to Ignore: Biomass Sourced From Naturally Managed Working Forests

May 23, 2018 by Roger Ballentine Leave a Comment



By Roger Ballentine and Jennifer Jenkins.

Outside the realm of climate change deniers, there is broad consensus that we need rapid and deep decarbonization of modern energy systems to have any chance of stabilizing global average temperature rise in the neighborhood of two degrees Celsius, the threshold widely viewed as critical for avoiding the most dangerous impacts of climate change.

However, the window of opportunity for achieving the emissions reductions needed to meet this target is narrowing quickly in the face of stubborn political and economic headwinds. We can't afford to wait: we need immediate emissions reductions, and we need them urgently.

Given these narrowing odds and the enormity of the climate crisis, any suggestion that we remove a potential low-carbon energy source or technology from our climate change mitigation toolkit bears a very high burden of proof.

This climate imperative has lessened the opposition from some environmentalists to certain energy options like nuclear power, carbon capture and sequestration, and hydropower. Forest biomass, however, is still subject to withering criticism by some in the environmental community, as well as by otherwise well-meaning commentators. The media firestorm over EPA Administrator Pruitt's recent announcement that the Agency plans to treat emissions from forest biomass energy as carbon neutral certainly has not helped elevate the debate.[3]

But categorically discounting the climate change mitigation offered by forest biomass could make the mission of rapid and deep decarbonization more difficult to achieve. Biomass can directly displace fossil fuels for energy production, and when harvested from certain forest landscapes we can – and should – treat that energy as a zero-carbon resource.

First, let's limit the scope of the discussion. We describe a framework appropriate for evaluating the climate impacts of a critical subset of forest biomass — bioenergy feedstocks harvested from privately owned "working" forests, such as are prevalent in the southeastern United States – based on net changes in carbon stocks on the lands from which the biomass is harvested.

With this focus, we need not debate clearly "bad" biomass (*e.g.*, biomass harvested from otherwise untouched or conservation forests) or clearly "good" biomass (*e.g.*, wood wastes or residues from commercial forestry operations that would otherwise be burned or left to decompose on site) – we should not use the former and there is not enough of the latter to make a meaningful difference.

We are also not addressing here the very important concerns about how forest product harvesting can impact important issues like biodiversity, water quality, or habitat value. These concerns are not germane to determining the ultimate climate impact of bioenergy but can – and should – be addressed by separate sustainability guidelines and best practices.

Energy from biomass harvested from managed working forest landscapes where growth outpaces harvest is zero-net-carbon energy.

Yes, biomass combustion emits CO_2. And yes, it's true that biomass utilization can be less efficient, in terms of CO_2 emitted per unit of energy produced, than fossil fuels in conventional thermal and power plants. And while it is true that a molecule of emitted CO2 has the same warming impact regardless of its source, it does not necessarily follow that emissions from biomass combustion should be treated as new net-positive CO2 added to the atmosphere.

If biomass energy feedstocks come from working forest systems in which harvested wood is continually and in real time completely replaced by new growth — the substitution of this energy source for fossil fuel eliminates fossil emissions without adding any new and net incremental CO_2 to the atmosphere at the time of combustion.[4]

A market for sustainably sourced bioenergy creates incentives for better forest management and the maintenance of net carbon stocks, particularly on privately owned lands.

Many criticisms of forest bioenergy make the mistake of not distinguishing managed working forests, like those in the southeastern U.S. that are managed in such a way as to maintain net carbon stocks, from other types of forest landscapes, such as conservation lands.

The private working forest landscape in the Southeast is managed to continually produce an array of products into the forest products market, only a small portion of which are bioenergy feedstocks. And by "managed" we mean that harvest, growth, and regeneration are constantly occurring across the forest landscape so that when one stand is harvested, the carbon removed from that pool is being returned by new growth elsewhere on the landscape[5].

While one could argue that the most climate beneficial management approach would be to let forests grow unfettered without ever harvesting them, that scenario is not the relevant or realistic "counterfactual" *for private working forests, particularly in the SE, which is one of the most productive commercial wood-producing regions in the world.*Rather, research on this question suggests that the opposite is true.

Absent demand for forest products – including an economic outlet for low-value fiber such as that used for energy — the working forest landscape in the U.S. Southeast would grow more slowly with respect to the amount of merchantable timber they produce or possibly even decline, and therefore would likely sequester less carbon.[6]

We know this because there is a positive relationship between forest harvest and forest growth in these landscapes: somewhat counterintuitively, it is the profitable harvest of trees that give landowners the reason to continue actively managing these forests for growth and bioenergy markets are a key part of these economics (providing a market for low-quality material harvested from the forest but undesirable for other uses).

And if these working forests are not producing profits for the landowner there is the additional risk they could be converted to another revenue-generating use involving the clearing of part if not all of the forest – the worst possible climate outcome.[7]

For managed working forests, a focus on the temporary CO_2 emissions of a given isolated harvest misses the larger climate-relevant point.

Without question, harvesting and combusting biomass from a forest stand results in net emissions*from that forest sub-unit* until the stand in question regrows biomass equal to what was harvested from it.

But for a working managed forest landscape, at any given time, across all the different stands that make up that landscape, the forest is yielding emissions from those units being harvested *while simultaneously* sequestering carbon as a result of new growth and regeneration in other units harvested previously. This is how sustainably managed working forests have always operated.

Every year in the southeastern U.S., 2% of the working forest is being harvested while the remaining 98% is in various stages of regrowth (and within that 2%, several different forest products are produced, a small but economically important portion of which is biomass for energy use). The International Energy Agency (IEA) has described the role of bioenergy production in sustainably managed forests:[8]

Biomass extraction for energy is one of many interacting factors influencing the development of forest carbon stocks, including forest product markets, forest ecosystem structure and management, and natural conditions. Silvicultural operations and harvest activities are coordinated across a forest landscape to maintain a healthy forest and to obtain a continuous flow of wood for society, while maintaining or increasing wood volume in the forest. Carbon losses in some stands are balanced by carbon gains in other stands, so that across the whole forest landscape the fluctuations in carbon stock even out.[9]

Building a carbon accounting policy framework for working forests by attempting to model emissions and sequestration for an individual tract at the stand level ignores the carbon that is being re-sequestered by the re-growing portions of the previously harvested landscape; only simultaneous analysis of emissions and regrowth can determine the net climate impact of a given landscape. The production of wood in response to market demand is enabled by the simultaneous management of a very large number of stands on the landscape, not by management of one individual tract over time.

If there is net sequestration at the scale of the managed forest landscape, then a specific harvest within that landscape is*not* a net emission that must be "accounted" for; the climate is receiving a net CO2*benefit* or dis-benefit depending on the change in carbon stocks on that managed forest landscape. Themanagement of the working forest system *as a whole, land-use trends, changes in carbon stocks, net storage in long-lived products as well as the impact on the use of other products*determines the net climate impact.

For those steeped in the language of corporate carbon accounting, net climate impact is how we do carbon accounting and reporting. One could analogize to how a corporation reports and tracks greenhouse emissions. A given factory or

facility, for example, may produce an increase in emissions (as might a portion of a working forest), but if other units of the company reduce their emissions correspondingly, the company reports no net increase in emissions.

Similarly, if there is a net increase in carbon stocks year over year in a given working forest landscape then the use of forest products for energy should not be "assigned" emissions independent of the net sequestration of the working forest landscape from which they came.

An approach that focuses on actual, measured changes in carbon stocks over time is more practical and offers greater assurance of climate benefits than an approach that relies on speculative modeling and unrealistic "counterfactuals".

Some forest bioenergy critics take the position that climate benefits should be assessed by comparison to modeling scenarios that assume no forest harvest at all, or perhaps no forest harvest for energy purposes. Modeling is not the best way to formulate a carbon policy, because modeling alternative scenarios is complex and necessarily entails numerous assumptions and as a result to date has proven ineffective at predicting future trends.

Modeling inevitably includes the heroic assumption that a model can reliably predict what would happen to future markets for forest products absent the additional driver of demand for energy applications. And perhaps more importantly, a counterfactual of unfettered growth with little or no harvesting is simply not applicable for most private working forests such as those that are prevalent in the southeastern U.S. Without harvest (and the income it generates), some portion of these forests assets is likely to be converted to crops or other non-forest uses.

There is no need for speculative modeling: measured data can be used to determine if the forest landscape is, in net, sequestering or losing carbon. If (and only if) it is net sequestering, then energy from biomass harvested from that landscape should be treated as carbon-neutral. The European Union's proposed clean energy policy follows this approach.[10]

Far from labeling all biomass, regardless of its source, as "carbon neutral," a landscape-level, carbon stock framework for managed working forests appropriately bounds the designation of climate-beneficial forest biomass energy.[11]

Such a carbon accounting policy approach, along with other non-carbon environmental safeguards, will help maintain a viable forest products industry, incentivize sustainable forest management, and ensure that appropriately-sourced bioenergy remains available as an alternative to fossil fuel use.

Policies pertaining to forest bioenergy, whether they are imposed by governments or adopted voluntarily, must reflect several key points:

- We should not categorically remove forest biomass from our climate mitigation toolkit and we need not label all biomass as "carbon neutral". We should use biomass from landscapes where carbon stocks are stable or increasing and where adequate sustainability standards are met.
- Owners of working forests are more likely to manage their assets in ways that foster stable or increasing carbon stocks when markets for forest products are robust. Perhaps counterintuitively, research suggests that increased demand for forest biomass can lead to management practices that are more likely to maintain forest carbon.
- Modeling is not needed to apply this framework, since there is an existing robust system for providing actual regional inventory data can be used to directly quantify carbon stocks at the landscape scale.
- Important international scientific bodies and environmentally progressive governments support the landscape carbon stock approach.
- The landscape/sustainable harvest approach will give would-be bioenergy consumers clear guidance as to a carbon neutral subset of biomass they can source.
- Simply limiting biomass energy use to very narrowly sourced feedstocks (such as sawmill residues) will miss the opportunity to further reduce net carbon emissions to the atmosphere as the supply chain will be inadequate to enable fossil users to invest in conversion; these users will

transition to lower carbon options only if they can secure a supply base at scale that can guarantee bankable delivery.

As in most energy and climate debates, the issues surrounding forest biomass are complex. All energy production technologies, including options like wind and solar, have advantages and drawbacks, and all have elicited legitimate environmental concerns. Biomass is no exception and its specific attributes mean that it will be important to apply robust sustainability criteria and other environmental protections—including tracking of net carbon stocks in source forests—as a condition of using additional wood for energy production.

But biomass has advantages, in terms of supply reliability and compatibility with existing energy infrastructure that can accelerate the displacement of fossil fuels in the near term. A policy based on unrealistic counterfactuals or that focuses only on the carbon impacts in only a subset of a larger working forest misses the forest for the trees, so to speak, and risks foregoing a low-carbon energy option that—given the scale and urgency of the climate challenge—we can ill afford to lose.

By Roger Ballentine[1] and Jennifer Jenkins[2]

1 Roger Ballentine is the President of Green Strategies, Inc. He served as Chairman of the White House Climate Change Task Force under President Bill Clinton and is the Co-Chair of the Aspen Institute Clean Energy Innovation Forum.

2 Jennifer Jenkins is Vice President and Chief Sustainability Officer at Enviva Biomass. She holds a PhD in ecosystem ecology from the University of New Hampshire and a Master of Forest Science from Yale University's School of Forestry and Environmental Studies.

3 In the current environment it is hard to separate the details of any EPA policy from its controversial Administrator. We don't here defend or dissect what EPA did, but EPA has not indicated that carbon neutrality is assumed automatic under all circumstances and for all time: EPA has committed to revisit its policy should the trajectory of US carbon stocks shift. Irrespective of EPA's policy, we

suggest a narrow framework that can put the right biomass into our climate toolkit.

4 Of course, the production and transportation of bioenergy products like pellets have emissions associated with them. It is the same with the production and transportation of Chinese solar panels. We do not attribute such supply chain emissions to the emissions rate of the energy eventually produced.

5 Note that typically a share of the carbon removed from the forest – the portion of the harvested timber that is sold into sawtimber markets – is stored over the long term in harvested wood products, providing additional sequestration. Far from reducing these climate-helpful uses of forest biomass, a market for low value fiber such as for bioenergy helps support the economics of these uses.

6 According to a report published in July 2017 by Forest2Market that examined data from the U.S. Department of Agriculture's Forest Service Forest Inventory and Analysis for the southeastern U.S. over the six decades from 1953 to the present. Over that period, the data confirm a positive relationship between forest harvest and forest growth, indicating that landowners responded to a stable market for forest products by planting more trees. Jefferies, H.M., T. Leslie. 2017. Historical Perspective on the Relationship between Demand and Forest Productivity in the US South.
https://blog.forest2market.com/forest2market-report-shows-increased-demand-for-wood-fiber-leads-to-forest-growth

7 Dale, V. H., Kline, K. L., Marland, G., & Miner, R. A. (2015). Ecological objectives can be achieved with wood-derived bioenergy. The Ecological Society of America Frontiers in Ecology and the Environment, 297-299.

8http://www.ieabioenergy.com/

9https://www.chathamhouse.org/sites/files/chathamhouse/publications/2017-04-05-IEABioenergy.pdf

10 The current version of the EU's RED2 package, "Clean Energy for all Europeans," considers the use of U.S.-sourced biomass in stationary facilities

such as power plants as a greenhouse gas reduction tool only if the biomass is sourced from a supplier whose forest stocks are stable or increasing. As agreed by Plenary Vote in the EU Council on December 18, 2017 and by Plenary Vote in the EU Parliament on January 17, 2018.

11 Moreover, there is little potential for detrimental "leakage" from these forests whereby increased demand for bioenergy from managed forests shifts overall demand and results in increased harvesting from forests that are not managed for continued growth. The decline of the region's pulp and paper industry since the 1980s (due to a broader reduction in demand for paper and printed products) has made an abundance of low-quality feedstocks available. Woodall, C. W., Ince, P. J., Skog, K. E., Aguilar, F. X., Keegan, C. E., Sorenson, C. B., . . . Smith, W. B. (2012). An Overview of the Forest Products Sector Downturn in the United States. Journal of Forest Products, 595-603. Further, even if concerns remained about demand for feedstocks increasing to the point where local leakage became a problem, these concerns could be mitigated by monitoring the forest landscape over time to ensure that overall carbon stocks are stable or increasing. Provided the landscape carbon stock analysis is conducted over an area large enough to capture any effects of leakage outside a given producer's supply region, this approach would provide confidence that the use of the producer's feedstocks for energy purposes is not leading to additional greenhouse gas emissions.

Photo Credit: Andrea Kirkby via Flickr



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LTC Action Comments for the Record
Senate Energy and Natural Resources Committee Hearing
"The Department of Energy's Carbon Capture, Utilization, and Storage Programs and to Receive Testimony on *S. 1201, the Enhancing Fossil Fuel Energy Carbon Technology Act of 2019*"
May 16, 2019

May 29, 2019

LTC Action appreciates the opportunity to submit comments for the official record on the Committee's May 16th hearing on the Department of Energy's carbon capture, utilization and storage (CCUS) programs and S.1201, the *Enhancing Fossil Fuel Energy Carbon Technology Act of 2019*. Our comments enclosed herein focus on carbon dioxide removal because of the critical role that it needs to play in addressing climate change, particularly Section 5 of S.1201.

LTC Action is a 501(c)(4) entity, related to the Linden Trust for Conservation, that engages in direct advocacy around U.S. climate policy. We support ambitious federal climate policy broadly, with a particular focus on policies that support carbon dioxide removal (also known as "CDR" or "negative emissions"), a heretofore under-resourced set of technologies that capture and sequester carbon dioxide (CO_2) from ambient air. In 2018, the Intergovernmental Panel on Climate Change's (IPCC) special report on *Global Warming of 1.5° C* found that all pathways limiting warming to 1.5° C must rely on significant deployment of CDR over the 21st century, along with most scenarios limiting global warming to 2° C. The scale of this required carbon removal is substantial—as much as 20% of today's global emissions annually by 2050 and double that level by 2100.

Therefore, it is essential that Congress put in place a robust set of federal research, development, demonstration and deployment (RDD&D) CDR policies and programs to help meet the many challenges posed by climate change. While robust federal action is needed, S.1201 recognizes the need for a first-of-its-kind RD&D program dedicated to the indispensable suite of carbon removal technologies. As detailed below, LTC Action believes Section 5 of S. 1201 could be improved through a series of refinements, which would help to focus resources on these emerging technologies.

The legislation's carbon removal research program represents an important first step in keeping with the central recommendation of the National Academy of Sciences in its 2018 report, *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda.* The National Academies (NAS) recommended in the report that the U.S. "launch a substantial research initiative to advance negative emissions technologies [CDR] as soon as practicable." The urgent need to address climate change justifies this investment, and multiple market-sizing analyses have determined that the investment would reap substantial economic returns. NAS highlights that advances in CDR "will benefit the U.S. economy if the intellectual property is held by U.S. companies." LTC Action

believes Congress should heed the National Academies' recommendation and dedicate significant resources to launching this initiative.

Focusing research on the highest-impact carbon removal opportunities

There are many approaches to removing carbon dioxide from the atmosphere:

- *Direct air capture (DAC)* uses a chemical and mechanical process to capture CO_2 directly from the air and concentrate it for underground sequestration or use in new materials
- *Bioenergy with CCS* captures CO_2 through plant photosynthesis and then recaptures the carbon emitted during bioenergy production
- *Enhanced geological weathering* reacts CO_2 with naturally reactive rocks to lock the carbon away in mineralized form
- *Agricultural and grazing practices* increase CO_2 uptake in soils
- *Forest management and afforestation* absorb CO_2 in trees

The list above is not exhaustive, since researchers are actively exploring other techniques to remove CO_2 from the atmosphere. LTC Action encourages Congress to pursue a comprehensive portfolio of these and other carbon dioxide removal solutions that will be necessary to achieve our climate objectives.

At the same time, Congress must institutionalize carbon dioxide removal RD&D within the appropriate agencies and offices and ensure they are fully resourced. Therefore, we urge the committee to narrow the scope of activities in the carbon dioxide removal program created by S.1201 (subsection (c) of section 5) by restricting the RD&D to "direct air capture and storage technologies" and "enhanced geological weathering." These programs are the most germane to the Department of Energy's Fossil Energy office (FE), as FE has already carried out some research into DAC and the office's extensive experience managing CCS research complements the RD&D needs of DAC. FE's expertise with mineral drilling and manipulation also makes it well suited to lead on enhanced geological weathering.

Given federal budget constraints, narrowing the scope of carbon removal RD&D in the legislation will also help ensure that DAC and enhanced geological weathering are adequately resourced and prioritized. The National Academies notes that, unlike other approaches, these two technologies have "essentially unlimited" carbon removal capacity if research can lower costs. Meanwhile, the federal government has already dedicated significant resources to forestry, soil and bioenergy research but comparatively little to DAC or carbon mineralization. Given this disparity and the Department of Energy's proven track record of facilitating cost declines for emerging technologies through RD&D, it is our belief that DAC and enhanced geological weathering represent the highest marginal value opportunities for new research funding.

The Energy and Natural Resources Committee could improve the carbon removal section of S.1201 in two additional ways:

- Increasing the authorization of appropriations for the first year of RD&D to $60,000,000, which approaches the amount of funding NAS recommends for DAC alone. Later years should be increased a corresponding amount.
- In addition, Congress should authorize $15,000,000 in the first year for the establishment of a DAC test center, with increasing funding in later years. The NAS recommends establishing such a test center to support pilots and demonstration projects.

These changes would make the carbon removal provisions in the *EFFECT Act* more consequential, by focusing the scope on technologies well within the purview of the Fossil Energy Office and giving DOE the tools and resources necessary to carry out meaningful research, development and demonstration activities.

LTC Action stands ready to answer questions or assist with any of the aforementioned recommendations. Thank you again for the opportunity to highlight the importance of carbon dioxide removal to U.S. climate policy, and thank you for your leadership on this critical issue.

National Wildlife Federation
National Advocacy Center
1200 G Street NW, Suite 900 • Washington, DC 20005 • 202-797-6800

May 28, 2019

The Honorable Joe Manchin
U.S. Senate
306 Hart Senate Office Building
Washington, DC 20510

Dear Ranking Member Manchin:

On behalf of the six million members and supporters and 51 state and territorial affiliates of the National Wildlife Federation, I would like to express appreciation to you and the original cosponsors of the EFFECT Act (S. 1201) for putting forward a pragmatic proposal to spur the innovation of carbon removal and storage technologies in order to reduce net greenhouse gas emissions. We support moving quickly towards net-zero emissions by mid-century, recognizing that successfully stabilizing our climate can only come from developing and utilizing all feasible low- and zero-carbon technologies and carbon removal strategies.

In particular, we appreciate the following key elements of the bill:

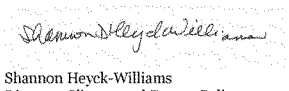
- Authorization of a technology program at the Department of Energy that would use research and development, large-scale pilot projects, demonstration projects, and an engineering and design program to employ carbon capture, utilization, and sequestration technologies to decrease the carbon dioxide emissions from new and existing coal and natural gas power plants and other industrial facilities;
- Inclusion of additional programmatic goals to: support safe geological storage of carbon dioxide emissions, improve use and reuse of captured CO_2 in other end-products, develop net-negative CO_2 emission technologies, and decrease the non-CO_2 environmental impacts of coal and natural gas;
- Establishment of a Carbon Removal Program in coordination with the Department of Agriculture and other agencies to test, validate, or improve other technological and natural strategies to remove CO_2 from the atmosphere on a large scale, such as direct air capture technologies, geological weathering, agricultural practices, and forest management. We especially appreciate the bill's consideration of land use changes and how those affect net greenhouse gas emissions, as well as natural and managed ecosystems; and
- Requiring the National Academies of Science to study barriers and opportunities to commercializing carbon dioxide in the U.S.

As the bill advances through the committee process, we look forward to working with you to make improvements in the following areas:

- Strengthening the criteria for biomass energy-associated carbon capture research, development, and demonstration and pilot projects to ensure:
    - "Sustainable" – in lieu of "renewable" – sourcing;
    - Inclusion of a carbon lifecycle analysis requirement that takes account of indirect and direct land use effects and potential for net-negative carbon sequestration in the near-term; and
    - Consideration of wildlife habitat impacts;
- Expanding the carbon utilization program's scope to include products to improve agricultural production, forest health, or water quality;
- Expanding the carbon removal program's scope to include activities related to grassland conversion and restoration, plus blue carbon captured by coastal ecosystems, and refining forestry activities to focus on improved forest management, reforestation, and ecologically-appropriate afforestation; and
- Ensuring the carbon removal program considers impacts on wildlife populations.

Thank you again for your leadership on this thoughtful bill, and for working with Chairman Murkowski to examine solutions to the growing threat of climate change, which is already resulting in dire impacts in states such as West Virginia and Alaska.

Sincerely,



Shannon Heyck-Williams
Director, Climate and Energy Policy

Cc: The Honorable Lisa Murkowski
The Honorable Shelley Moore Capito
The Honorable Steve Daines
The Honorable Kevin Cramer

