

**Energy and Environmental Innovation:
Wyoming's Leadership in Using and
Storing Carbon Dioxide Emissions**

FIELD HEARING

BEFORE THE

**COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS**

UNITED STATES SENATE

ONE HUNDRED SIXTEENTH CONGRESS

SECOND SESSION

AUGUST 19, 2020

Printed for the use of the Committee on Environment and Public Works



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

U.S. GOVERNMENT PUBLISHING OFFICE

42-119 PDF

WASHINGTON : 2020

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

ONE HUNDRED SIXTEENTH CONGRESS
SECOND SESSION

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Energy and Environmental Innovation: Wyoming's Leadership in Using and Storing Carbon Dioxide Emissions

WEDNESDAY, AUGUST 19, 2020

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, DC.

U.S. Senate Committee on Environment and Public Works Washington, DC.

The committee met, pursuant to notice, at 10:00 a.m. at the Wyoming Integrated Test Center, 12480 N. Highway 59 Gillette, WY 82716, Hon. John Barrasso (chairman of the committee) presiding.

Present: Senators Barrasso, Enzi, and Mr. Luthi.

OPENING STATEMENT OF HON. JOHN BARRASSO,
U.S. SENATOR FROM THE STATE OF WYOMING

CHAIRMAN BARRASSO: Good morning. I call this hearing to order and welcome everyone who is here. Please have a seat, make yourself at home, and make yourself comfortable.

The Senate Environment and Public Works Committee is honored to convene today in Wyoming for a field hearing at the Wyoming Integrated Test Center.

In addition, I really want to thank Senator Enzi, a Wyoming senior senator; he is the Chairman of the Senate Budget Committee. However, most importantly, he is a former Mayor of Gillette, Wyoming. Moreover, I want to thank him for joining us here today.

Mike, we are normally doing Wyoming Wednesdays in Washington with doughnuts and coffee and juice with everyone from Wyoming. I guess, I wanted to get doughnuts, but they said due to Coronavirus, I could not have boxes of doughnuts here today. Therefore, we can't quite do Wyoming Wednesday. Nevertheless, it's a pretty good group.

SENATOR ENZI: It is, yes.

CHAIRMAN BARRASSO: Looking at all the folks who are here today.

Well, today we are here to discuss Wyoming's leadership in using and in storing carbon dioxide emissions. Just outside these doors is a world-class facility where research is currently underway to study how we can create commercial currently

underway to study how we can create commercial value from carbon dioxide that would otherwise just go up into the atmosphere, located next to Basin Electric Dry Fork Power Station, and we were both here for the grand opening a dozen years ago.

The Integrated Test Center hosts research that will create new markets and new jobs in Wyoming. The center will research how to transform coal power plant emissions into building materials, like cement as well as alternative fuels.

Through our relationship with NRG Canadian Oil Sands Innovation, XPRIZE, the center will welcome five teams of researchers from around the world.

Last year I met with one of the finalist teams from Aberdeen, Scotland during a trip to their research lab. We had five senators that were on that trip, a bipartisan group, including Lisa Murkowski, the present Chairman of the

Energy Committee; Maria Cantwell, who has served as ranking member of that committee previously; Senator Sheldon Whitehouse from Rhode Island, and Joe Manchin from West Virginia.

It is not surprising that Wyoming can attract such top talent from around the world. Because in Wyoming, we are blessed with tremendous fuel resources, coal, natural gas, oil. In addition, most of that coal comes from right here, Mike, in your home community of Campbell County.

The world-class researchers at this center will study how to transform the carbon dioxide from burning these abundant fuel resources into a host of new and innovative applications.

These new applications can be added to currently viable commercial uses for carbon dioxide, a process that many of us know as enhanced oil recovery. It is already being used in Wyoming. With Randall Luthi here, it was being used when he was Speaker of the House of the Wyoming Legislature.

This is where carbon dioxide is injected to produce oil from older, more mature -- into older more mature fields. Once this process is complete, the carbon dioxide is then permanently stored underground.

If we can harness carbon dioxide from power plants and other facilities, Wyoming has the great potential for even broader scale enhanced oil recovery.

Wyoming has abundant, deep saline formations. These formations can store carbon dioxide deep underground instead of being released into the atmosphere. Scientists from the University of Wyoming, many are here today, were conducting geologic testing in a formation just a short distance from this center.

As Chairman of the Environment and Public Works Committee, in the United States Senate, carbon capture is one of my top policy priorities.

Two years ago, President Trump signed an extension and expansion of the 45Q tax credit for carbon capture facilities. Now

we must make sure that credit can be deployed and used to build new carbon capture projects.

In order to accomplish this goal, I have pushed the Internal Revenue Service, and specifically and directly the Secretary of the Treasury, to issue the much-needed guidance this year. Also, introduced legislation called the USE IT Act -- and that stands for Utilizing Significant Emissions and Innovative Technologies Act, USE IT Act -- to complement the 45Q tax credit. This bill ensures that Washington is a willing partner in the development of carbon capture projects.

The USE IT Act helps researchers find commercial uses for captured carbon dioxide emissions. It supports the use of carbon capture technology, including direct air capture.

The USE IT Act also directs the federal government to work with developers to expedite, not block, the permitting process. We know all too well that delayed permitting can kill important projects.

The USE IT Act also funds research such as the type of research occurring right here at the Integrated Test Center for carbon utilization as well as direct air capture.

The USE IT Act passed the Senate for a second time this Summer after passing the committee I chair unanimously 21 to nothing. Last year, House Democrats blocked it from becoming law. That was in the House, but we have unanimous agreement in the Senate. In addition, I am working to secure its passage into law this year.

Wyoming continues to be the leading state in the nation with regard to carbon capture research. So I am so pleased that today's hearing can be held to shine a spotlight on the great work that is happening right here in our state.

I would like to turn this over to Senator Enzi for any opening remarks he would like to make.

**OPENING STATEMENT OF HON. MICHAEL ENZI,
U.S. SENATOR FROM THE STATE OF WYOMING**

SENATOR ENZI: Thank you, John, and thank you for holding this hearing here. This is a very unusual testing center that will make a difference for the country. I thank you for your role in being the Chairman of the Environment and Public Works Committee that is infrastructure as well as environment.

I know that you are in line to be the Chairman of the Energy Committee as well. That will definitely be a help to this entire process.

Besides that, of course, John is one of the leaders in the Senate. He is one of the top -- he is in the five people who get to make the important decisions for what we are going to do and how we're going to do it. He does an outstanding job with that, as well as presenting the case to the nation. Therefore, I am thankful for you doing this hearing. I know it will make a difference.

I want to welcome everybody to Campbell County. Chairman of the county commission is here today, and others. I used to be the mayor here. You will see the symbol for the city is the energy

capital of the nation. That is because in this county, we have more BTUs of energy than Saudi Arabia has.

We can utilize it, or we can pass it over. Many jobs rely on that, and the jobs are well-paying jobs for thousands of people. The state relies on the revenue, as do all of the entities of the state, from the energy of this area.

They are noticing the lack of oil production at the moment. For the first time in over 130 years, there is not a drilling rig operating in Wyoming. I think that is going to affect airplanes at some point because they still cannot run on solar.

However, I am so pleased that you are holding this. I want to thank all the witnesses to this important work to make this facility a success, and for the insights and experiences that you can share with us.

It has been great to work with Senator Barrasso as we try to incentivize growth in this industry through the 45Q tax credit and his USE IT Act.

For a long time we have said the people of the United States are the most innovative people in the world. Of course, I like to think the people in Wyoming are the most inventive people anywhere.

Part of it is because of our distances, and we travel a lot. When you are traveling, you think about other things, like what your job is and how much better it could be. Consequently, Wyoming per capita has more patents than any other state. So, we are always thinking.

Of course, we appreciate the University of Wyoming and community colleges who are taking our young people and educating them to think that -- to increase their thinking ability from the way that they have grown up having to innovate. We know that will make an important difference for the state.

It is important, more important than ever that Wyoming and the federal government work together with the universities and with the private sector to invest in technology innovation in order to create a sustainable future, particularly for coal, but for all energy.

I will continue to support policies that help push this innovation forward and ensure that Wyoming remains the epicenter for these technologies.

There are some amazing things going on, not only here but also at the university that will make a difference. At the university, they have one test center that is figuring out how to get oil out of granite, and I think they are making progress.

However, we need to make sure that oil is still necessary and as clean as possible. I have confidence that the innovation and inventiveness of the Wyoming people and the people in the United States will make that happen.

Nothing that the federal government does is worth much unless there is talented and capable people on the ground to put the policies into action.

And I'm looking forward to our discussion and learning more about how we can work together to continue advancing these technologies, and the ones that will come out of this.

I am on the Health, Education, Labor and Pensions Committee, and one of the stunning things that I ran into there is that the average kid that is in junior high right now will have over 15 different occupations based on how technology is moving ahead. Moreover, what really stunned me was, 11 of those have not even been invented yet.

Therefore, the world is going to change. We need to make sure we are educating our kids so that they take advantage of that change and make the change. This is one of the places where that change can be made.

Therefore, John, I really appreciate you holding the hearing here and bringing to light some of the opportunities that we have. That is how we have to look at any problem, as an opportunity. So thank you, John.

CHAIRMAN BARRASSO: Well, thank you, Mike. You know, you look around the room and talk about your time here as mayor, and my time in the legislature, your time in the legislature and now in the senate.

I am going to introduce our friend, Randall Luthi in a few moments as the Chief Energy Advisor to Wyoming Governor Gordon.

You know, you look, there's Jim Anderson, he was probably here in Gillette when you were mayor, and now you got -- and you will -- got reelected last night, you won your primary to the State Senate in Natrona County. So congratulations. I know it was a late night.

Although the results on your race were in pretty early.
Congratulations.

You know, it's fun to have Rita Meyer here, former auditor.
We have -- talk about leadership at the local level, we have
Rusty Bell here from the county commission, and as a graduate of
Leadership Wyoming, and all the activity there. It is nice to
have Ed Seidel here, President of the University of Wyoming.

So we are represented all across the board with people
committed to Wyoming and to the nation and to energy and the
needs that we have and that we have the availability right here
in Wyoming.

With that, I would like to introduce, and it is a great
pleasure to introduce, Randall Luthi, who is the Chief Energy
Advisor to Wyoming Governor Mark Gordon. He is an attorney, a
rancher, former Speaker of the Wyoming House of Representatives.
He brought considerable insight and experience to the governor's
office, and we are grateful for that.

Prior to joining the governor's office, he was President of
the National Offshore Ocean Industries Association. He knows lots
about energy onshore and offshore.

He served in the Department of Interior as the Director of
Minerals Management Service, and is Deputy Director of the
Department's Fish and Wildlife Service. Had the pleasure of
serving with him in the Wyoming legislature for many years. Proud
to continue to work with him on behalf of the people of Wyoming.

You testified last year at the Senate Environment and Public
Works Committee.

Welcome here today, Randall.

**STATEMENT OF RANDALL LUTHI, CHIEF ENERGY
ADVISOR TO GOVERNOR MARK GORDON**

MR. LUTHI: Well, thank you very much.

Thanks for those kind words, Chairman Barrasso, Senator Enzi. On behalf of Governor Gordon, welcome home.

Senator Enzi, this is like double home for you. You know, not only in the state, but as everybody has pointed out, but in Gillette as well.

You know, the work you both do in D.C. is so vital to the people of Wyoming. It is your dedication to return regularly to the state to find out what is relevant is what keeps you well-grounded. The Governor appreciates that. The people of Wyoming appreciate that.

Thank you for your efforts, particularly in this last -- this calendar year, as we have faced the oil wars, unwarranted market pressures on coal, and a pandemic. You know, we no longer muse in the governor's office about what else could go wrong, for fear that it actually will.

So on a more personal note, you know, I did have truly the pleasure and honor to serve with both of you in the legislature. I recall you represented your districts with honor and distinction, and you have continued to clear that high bar in the U.S. Senate.

Mike, Senator Enzi, today has to be a little bit bittersweet for you. As you think about it, how long has it been since you have not had your name on a ballot in the primary election?

However, I will bet you and Diana are already well in to making plans for doing something else for your next career. Again, thank you for a long, I describe it as just, put your head down and work career of public service.

All right. Back to the business at hand. You have chosen wisely to hold a field hearing at the Integrated Test Center. This center represents innovation, cooperation, and hope for our future.

This center wouldn't be here except for the cooperation and the generosity of electric utilities, the State of Wyoming, the community of Gillette, Campbell County, U.S. Department of Energy, and in particularly those willing to push the envelope, such as XPRIZE participants.

You know, at a time when so many loud voices -- and I think it's the loud voices of a few, that are calling to remove fossil fuels from our energy portfolio, this center provides an opportunity to focus on the real issue. How do we prevent or remove CO₂ from the atmosphere? What are the other uses of coal and CO₂ that could benefit our economy and consumers?

This center proves to be essential to our future livelihood and economy. Its work is exciting and has the full support of the Governor.

Although I am not a witness today, the Governor certainly supports measures such as the USE IT Act. Wyoming has enacted key legislation to promote the CO₂ capture. As you all know, the ability to use those 45Q credits is what is going to be make that work.

Our legislature is also looking forward.

Their almost two-year process to establish the Wyoming Energy Authority is complete or nearly complete. The Governor is committed to working with the WEA and support all forms of energy.

The ITC is essential in the Governor's energy and economic strategy. We are committed to ensuring that the strengths of the Wyoming infrastructure authority and the Wyoming pipeline authority remain and are available to assist the stakeholders to those who generously invested in this one-of-a-kind center.

We do know there are challenges today, and there will likely be far more tomorrow.

Political winds change directions like a pinball at an arcade. However, we must all commit to a steady, sure-footed energy policy that provides stability, reliability, and availability of all energy resources.

So thank you again. Thank you for giving the governor's office a chance to welcome you, because there is -- you are always welcome.

The Governor looks forward to seeing both of you in the future. Thank you very much.

CHAIRMAN BARRASSO: Thanks, Randall. We really appreciate you being here, and all of your help and direction.

Now we are going to turn our panel of witnesses and I would invite the three of them to come up. Randall mentioned the XPRIZE, and we are very fortunate to have with us the executive director, Dr. Marcius Extavour, who is here overseeing and the executive

director related to the Carbon XPRIZE. We are grateful to have you.

We also have Dr. Holly Krutka, who is the Executive Director of School of Energy Resources at the University of Wyoming, as well as Jason Begger, who is the Deputy Director of the Wyoming Energy Authority and the Managing Director right here at the Wyoming Integrated Test Center.

We are going to start with Jason. Jason is the current Deputy Director, as I said, here through the Wyoming Energy Authority. Manages the Integrated Test Center. Grew up in eastern Montana, worked in Washington for a couple of members of Congress.

After his time there, he worked for the Petroleum Association for Wyoming, for Rio Tinto and that became Cloud Peak.

Graduated with a bachelor's degree from Montana State University; Master's in Business Administration from the University of Denver.

You were back in Washington to testify to the Environment and Public Works Committee. We are grateful for that. He and his family live outside of Cheyenne. It is a pleasure to have you join us today. Please proceed.

We are going to ask all of you to try to keep your remarks to about five minutes so we have time for questioning.

**STATEMENT OF JASON BEGGER, MANAGING DIRECTOR,
WYOMING INTEGRATED TEST CENTER**

MR. BEGGER: Thank you, Chairman Barrasso, Senator Enzi. I appreciate the opportunity to speak with you today.

As the Chairman said, my name is Jason Begger, and I am the Managing Director of the Integrated Test Center. A little over three years ago, I had the opportunity to testify before this committee in your hearing room in Washington. Therefore, it is a great honor to have you out at our facility today.

The ITC is a private/public partnership between the State of Wyoming, Basin Electric Power Cooperative, Tri-State Transmission and Generation Association, and the National Rural Electric Cooperatives Association, also known as NRECA.

We have also had various in-kind contributions from Black Hills Energy and Rocky Mountain Power. The value of the private sector stakeholders is immeasurable as they have direct experience with project management, technology review, and strong federal relationships.

This facility was authorized in 2014 by the Wyoming legislature, and what you see today has all occurred within the past six years. Through our coalition, we have constructed a facility, developed a communications plan, established business development strategies as well as all the necessary operational plans.

Through relationships with the Department of Energy's National Carbon Capture Center and the International Carbon Capture Test Center Network, we have been able to learn and share best practices. At the end of the construction, the facility came in 18 percent under budget, which provides additional funding for operations.

The ITC fills a very unique need within the United States. While developers have tested larger projects in the U.S., this is the only dedicated testing site... (Brief pause).

This is the only dedicated testing site that could host larger pilot and demonstration projects.

Currently, many DOE-funded projects must travel to Norway to scale up. The ITC provide an opportunity to spend those U.S. dollars here at a substantially reduced cost, providing better value to our taxpayers.

We have worked hard to forge a strong relationship with DOE and last summer hosted Assistant Secretary for Fossil Energy, Steve Winberg. Senator Enzi at that time was able to join us for that tour out here.

We recognize that while we have a great facility, we need DOE support to fund the projects we ultimately want to test and host here.

One important lesson we have learned is, scaling up technology takes a long time. It takes years to move through the funding opportunities, the design, the fabrication, and finally testing. In order to see the real fruits, we need long-term commitments from the federal government to support testing.

Our testing partners need to know that they will have the resources they need to methodically scale up and provide the types of technical assurances utilities need to feel comfortable commercializing the technologies.

The USE IT Act would greatly assist in this area. Many but not all of our potential tenants are seeking federal funding, and

whether or not they receive funding will determine if they can deploy on site.

Currently we have relationships with XPRIZE, which you'll hear about from Dr. Extavour, the Japan Coal Energy Center, also known as JCOAL, Kawasaki Heavy Industries, Columbia University, TDA Research, Membrane Technology and Research, Gas Technology Incorporated, Air Liquide, and the University of Kentucky.

With regards to the research community, we view them as partners not just tenants. One of the great benefits of the ITC is the blank canvas approach we can provide. We have ample physical space to host an array of technologies and add amenities as we grow.

We hope we can partner with our tenants to repurpose equipment that they may no longer need to provide expanded testing capabilities. A great example of this project is one that would grant their steam boiler to the ITC upon the completion of their test. Steam is an integral component of many carbon capture technologies that would be a valuable service to provide.

Lastly, I would like to touch upon how Wyoming views the ITC as a lynchpin for broader economic technology and development. We have worked closely with Campbell County, the School of Energy Resources, the Enhanced Oil Recovery Institute, the Wyoming Business Council, and many others.

We make sure prospective tenants are aware of the expertise and resources within each of these organizations and how they may be able to best assist to make the Wyoming experience as seamless as possible.

A win/win for Wyoming is first developing these technologies that can be employed to preserve the economic value of the fossil energy industry, and then capturing the manufacturing and technology development that is perfected at the ITC.

I appreciate the opportunity to speak with you today and will gladly answer any questions.

[The prepared statement of Mr. Begger follows:]

**Testimony Submitted to the United States Senate Committee on
Environment and Public Works**

**Energy and Environmental Innovation: Wyoming's
Leadership in Using and Storing Carbon Dioxide Emissions**

**Submitted by Jason Begger, Managing Director,
Wyoming Integrated Test Center,**

August 19, 2020

Mr. Chairman, I appreciate the opportunity to speak to you today. My name is Jason Begger and I am the Managing Director of the Wyoming Integrated Test Center. A little over three years ago, I had the opportunity to testify before this committee in your hearing room in Washington, so it is a great honor to host you today at our facility.

The ITC is a private/public partnership between the State of Wyoming, Basin Electric Power Cooperative, Tri-State Transmission and Generation Association and the National Rural Electric Cooperatives Association (NRECA). We have also received various in-kind contributions from Black Hills Energy and Rocky Mountain Power. The value of the private sector stakeholders is immeasurable as they have incredible experience with project management, technology review and strong federal relationships.

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The ITC fills a unique need in the United States. While developers have tested larger projects in the U.S., this is the only dedicated testing site that can host larger pilot and demonstration projects. Currently, many DOE funded projects must travel to Norway to scale up. The Wyoming ITC provides an opportunity to spend those U.S. dollars here at a substantially reduced cost, providing better value to our taxpayers.

We have worked hard to forge a strong relationship with DOE and last summer hosted the Assistant Secretary for Fossil Energy, Steve Winberg. We recognize that while we have a great facility, we need DOE support to fund the projects we

ultimately want to test here. One of the important lessons we have learned is scaling up technology takes a long time. It takes years to move through funding opportunities, design, fabrication and testing. In order to see the real fruits, we need long-term commitments from the federal government to support testing.

Our testing partners need to know that they will have the resources they need to methodically scale up and provide the types of technical assurances utilities need to feel comfortable commercializing the technologies. The USE IT Act would greatly assist in this area.

Many, but not all, of our potential tenants are seeking federal funding and whether or not they receive, funding will determine if they can deploy on site. Currently, we have research relationships with XPRIIZE, who you will hear about from Dr. Extavour, the Japan Coal Energy Center, Kawasaki Heavy Industries, Columbia University, TDA Research, Membrane Technology and Research, Gas Technology Inc., Air Liquide and the University of Kentucky.

With regards to the research community, we also view them as partners, not just tenants. One of the great benefits of the ITC is the blank canvas approach we can provide. This provides the physical space to host an array of technologies and add amenities as we grow. We hope we can partner with our tenants to repurpose equipment they may no longer need to provide expanded testing capabilities. A great example of this is a project that would grant their steam boiler to the ITC upon completion of their test. Steam is an integral component of many carbon capture technologies that would be a valuable service to provide.

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A win/win for Wyoming is first developing these technologies that can be employed to preserve the economic value of the fossil energy industry and capturing the manufacturing and technology development that is perfected at the ITC.

I appreciate the opportunity to speak with you today and will gladly answer any questions. Thank you.

CHAIRMAN BARRASSO: Thanks so much, Jason. We will get back to you with the questions in a few minutes.

I would like to turn to Dr. Holly Krutka, who is the Executive Director of the School of Energy Resources at the University of Wyoming. Immediately before joining the university, she served as Vice President for Coal Generation and Emissions Technologies at Peabody, the world's largest private sector coal producer.

She has held a variety of roles in the energy industry and has worked specifically on carbon capture during her career. However, she is an innovator herself, and actually holds three patents. Holds a bachelor's degree and a Ph.D. from the University of Oklahoma in chemical engineering.

She is a native of Oklahoma, and we are so pleased that she and her family have chosen to make Laramie their home. You may proceed.

**STATEMENT OF DR. HOLLY KRUTKA, EXECUTIVE
DIRECTOR OF THE WYOMING SCHOOL OF ENERGY (SER)**

DR. KRUTKA: Thank you. Mr. Chairman, Senator Enzi, I appreciate the chance to speak with you today about the opportunities to support energy innovation right here in Wyoming.

My name is Dr. Holly Krutka. I am the Executive Director at the University of Wyoming School of Energy Resources, or SER.

SER is focused on energy-driven economic development for the state of Wyoming, which means that we are focused on technologies that will help support the needs of Wyoming and its energy customers.

If there's one thing you take from my testimony, let it be that Wyoming is an ideal place to drive innovation and deployment of climate-focused technologies, such as carbon capture, use and storage, because the state boasts vast fundamental subsurface knowledge, world-class research programs, the ability to execute large demonstration projects, and the will to drive technology development with the necessary policy support that can ultimately result in commercialization.

The University of the Wyoming boasts a world-class research program in the Center of Innovation for Flow through Porous Media, led by Professor Mohammad Piri. The Center is located at University of Wyoming's High Bay Research Facility, which contains more than 90,000 square feet that make up, to the best of my knowledge, the world's largest experimental research facility focused on flow through porous media and problems associated with applications in hydrocarbon recover, geologic sequestration of greenhouse gases and more.

It has been developed using more than \$100 million of investment from the state of Wyoming and corporate sponsors. The Center provides imaging and flow capabilities at the atomic, nan, micro, and macro scales.

In the drive toward commercializing novel technologies, a commercial entity has been spun off and is offering services today.

SER and our project partners are reimagining the use of coal as we develop a thermo-chemical process that produces nonfuel and energy products from Wyoming coal to create products like soil amendments, building materials, asphalt replacements, electro-spun carbon fiber mats that can be used for energy storage and much more.

In addition, SER is developing a dry methane reforming catalyst that uses carbon dioxide and natural to generate syngas, which is carbon monoxide and hydrogen. Our current estimates are that this dry-methane reforming process could create hydrogen at half the cost of current steam methane reforming technologies.

This use for CO₂ is an important component of the thermo-chemical process because it allows all the products I mentioned to be created from Wyoming coal with most of the carbon locked up in the products and near-zero carbon footprint.

SER's Center for Economic Geology Research, or CEGR, is a group of applied geoscientists dedicated to developing opportunities to diversify Wyoming's economy and maintain competitiveness in a low-carbon energy future. It includes internationally recognized experts on the topic of CO₂ geologic storage.

Funded by the Department of Energy through the Carbon Storage Assurance Enterprise, or CarbonSAFE Program, CEGR is investigating the commercial feasibility of geologic CO₂

storage two million tons per years and a total of at least 50 million tons of CO₂, located right here at Dry Fork Power Plant.

This project, referred to as Wyoming CarbonSAFE, possesses favorable technical, economic, and policy attributes to advancing eventual commercialization of large-scale carbon capture and storage in a modern coal-fired power plant.

Another tool in Wyoming's CCUS tool belt is the Enhanced Oil Recovery Institute, or EORI.

EORI's mission is to facilitate a meaningful and measurable increase in recoverable reserves and production of oil and natural gas in Wyoming. While necessary to help drive state GDP, CO₂ enhanced oil recovery, or EOR, is also a commercial-scale climate change mitigation technology.

Historical storage of CO₂ with EOR typically sequestered .2 metric tons of CO₂ per barrel of oil produced. Today, with the current and next generation technologies being tested and applied in Wyoming, up to 0.5 metric tons of CO₂ can be stored per barrel of oil produced, with the possibility of storing even more CO₂ per barrel with further research.

These technologies can provide a three-fold increase in the amount of CO₂ stored, while producing the same amount of domestic oil.

The final ingredient needed to commercialize CCUS and other environmentally focused technologies is the right policy framework.

Wyoming has applied for, and should be the second state to receive Class VI well primacy, allowing the state to implement CCUS projects that are in its interests on a timeline that works for commercial developers.

In addition, SER's recently launched Center for Energy Regulatory and Policy Analysis, or CERPA, is embarking upon a variety of interdisciplinary energy policy studies to focus on the state of Wyoming's economy.

CERPA is poised to begin an assessment of Wyoming House Bill 200, which established a nation-leading CCUS standard for electricity generation. Among other CCUS-related activities, CERPA is also preparing model CCUS agreements under the Wyoming CarbonSAFE project.

Therefore, in summary, while we face many challenges in the global energy sector and with widespread deployment of CCUS, Wyoming stands ready to help and has the necessary tools to make CCUS and other energy technologies a commercial reality. Thank you.

[The prepared statement of Dr. Krutka follows:]

**Testimony Submitted to the United States Senate Committee on
Environment and Public Works**

**Energy and Environmental Innovation: Wyoming's
Leadership in Using and Storing Carbon Dioxide Emissions**

**Submitted by Dr. Holly Krutka, Executive Director of the
Wyoming School of Energy Resources (SER)
August 19, 2020**

Mister Chairman, members of the Committee, I appreciate the chance to speak to you today about the opportunities that support energy innovation right here in Wyoming. My name is Dr. Holly Krutka and I am the Executive Director of the University of Wyoming School of Energy Resources (SER). SER is focused on energy-driven economic development for the state of Wyoming, which means that we are

focused on technologies that will help support the needs of Wyoming and its energy customers.

If there's one thing you take from my testimony, let it be that Wyoming is an ideal place to drive innovation and deployment of climate- focused technologies, such as carbon capture, use and storage (CCUS), because the state boasts vast fundamental subsurface knowledge, world-class research programs, the ability to execute large demonstration projects and the will to drive technology development with the necessary policy support that can ultimately result in commercialization.

The University of Wyoming boasts a world-class research program in the Center of Innovation for Flow through Porous Media, led by Professor Mohammad Piri. The Center is located at University of Wyoming's High Bay Research Facility, which contains more than 90,000 square feet that makes up, to the best of my knowledge, the world's largest experimental research facility focused on flow through porous media problems with applications in hydrocarbon recovery, geologic sequestration of greenhouse gases, and multiphase fluid flow through porous media in other science and engineering applications. It has been developed using more than \$100 million investment from the state of Wyoming and corporate sponsors.



Figure 1. The High Bay Research Facility was inaugurated in August 2017.

The Center provides imaging and flow capabilities at the atomic, nano, micro, and macro scales. It is home to a large, high-caliber international research team that is focused on advanced reservoir characterization and enhanced hydrocarbon recovery studies with direct relevance to the technical challenges encountered during exploitation of unconventional and conventional reservoirs. They develop and utilize leading-edge technologies to gain significantly improved insights into complex recovery schemes deployed in the US and abroad including those in Wyoming, North Dakota, Texas (west Texas and Gulf of Mexico), South America, and the Middle East. In the drive toward commercializing novel technologies, a commercial entity has been spun off and is offering services today.

The drive toward innovation continues to our current location, at the Wyoming Integrated Test Center, where carbon capture and conversion technologies are being applied to coal-fired power plant flue gas. There are many more examples of applied research, demonstration and commercialization proceeding around the state.

SER and our project partners are reimagining the use of coal as we develop a thermo-chemical process that produces nonfuel and energy products from Wyoming coal, to create products like soil amendments, building materials, asphalt replacements, electro-spun carbon fiber mats that could be used for energy storage, and much more. In addition, SER is developing a dry methane reforming catalyst that uses carbon dioxide (CO_2) and natural gas to generate syngas ($\text{CO} + \text{H}_2$) that can be used to produce petrochemicals or, alternatively, carbon monoxide-based chemicals and hydrogen. Our current estimates are that this dry-methane reforming process could create hydrogen at half the cost of current steam methane reforming technologies. This use for CO_2 is an important component of the thermo-chemical process because it allows the products I mentioned to be created from Wyoming coal with most of the carbon locked up in the products and near-zero carbon footprint.

SER's Center for Economic Geology Research (CEGR) is made up of internationally recognized experts in the topic of CO_2 geologic storage. Funded by the Department of Energy through the Carbon Storage Assurance Enterprise (CarbonSAFE) program, CEGR is investigating the commercial feasibility of geologic CO_2 storage of two million tons per year and a total of at least 50 million tons of CO_2 , located right here at Dry Fork Station. This project—referred to as Wyoming CarbonSAFE—possesses favorable technical, economic, and policy attributes to advance the eventual commercialization of large-scale, carbon capture and storage at a modern coal-fired power plant. CEGR is a group of applied geoscientists that explores Wyoming's distinctive geology for energy storage, critical minerals development, CO_2 sequestration, oil and gas recovery and more. CEGR is dedicated to developing these opportunities to diversify Wyoming's economy and to maintain competitiveness in a low-carbon energy future.

The Enhanced Oil Recovery Institute's mission is to facilitate a meaningful and measurable increase in recoverable reserves and production of oil and natural gas in Wyoming. While necessary to help drive the state GDP, CO_2 enhanced oil recovery (EOR) is also a commercial-scale climate change mitigation technology. Historical storage of CO_2 with EOR typically sequestered 0.2 metric tons of CO_2 per barrel of oil produced. Today, with the current and next generation technologies being tested and applied in Wyoming, up to 0.5 metric tons of CO_2 can be stored per barrel of oil produced. With funding from the Department of Energy, SER, EORI, and CEGR are testing new methods - next generation residual oil zones (ROZ) and next generation EOR storage plus - that could store >0.6 metric tons of CO_2 per barrel of oil produced. These technologies could provide

a threefold increase in the amount of CO₂ stored, while producing the same amount of oil.¹

The final ingredient needed to commercialize CCUS and other environmentally focused technologies is the right policy framework. Wyoming has applied for, and should be the second state to receive, Class VI well primacy, allowing the state to implement CCUS projects that are in its interests on a timeline that works for commercial developers. In addition, SER's recently launched Center for Energy Regulatory and Policy Analysis (CERPA) is embarking upon a variety of interdisciplinary energy policy studies to focus on the state of Wyoming's economy. CERPA is poised to begin an assessment of Wyoming House Bill 200, which established a nation-leading CCUS standard for electricity generation. The legislation will be implemented by the Wyoming Public Service Commission in the years ahead. Among other CCUS-related activities, CERPA is also preparing model CCUS project agreements for the Wyoming CarbonSAFE project.

In summary, while we face many challenges in the global energy sector and with widespread deployment of CCUS, Wyoming stands ready to help and has the necessary tools to make CCUS and other energy technologies a commercial reality.

¹ "Establishing a Business Case for CO₂-EOR with Storage", Wyoming Oil and Gas Fair 2018, Michael Godec, Advanced Resources International, Inc.

CHAIRMAN BARRASSO: Well, thank you for your thoughtful testimony. We will get to them in a moment.

I'm now delighted to welcome Dr. Marcius Extavour here, who is -- has a Ph.D. as well as a master of science in physics from the University of Toronto, where he explored the quantum mechanics of light and matter near absolute 0. He also holds a bachelor of science in engineering science from the University of Toronto where he built a pancake-making robot.

Pretty good.

Combined nano technology, nanomaterials with solar cells. You need to meet the president of the University of Wyoming who has a relativistic astrophysics Ph.D. on the collision of black holes. So between the two of you, I -- you know. Jim Anderson, be careful, you are in between the two of them.

(Discussion held off the record.)

CHAIRMAN BARRASSO: We are delighted you are here with us today, and in charge of the XPRIZE project. Please proceed with your testimony.

**STATEMENT OF DR. MARCIUS EXTAVOUR, EXECUTIVE
DIRECTOR, NRG COSIA CARBON XPRIZE**

DR. EXTAVOUR: Thanks very much.

Mr. Chairman and Senator Enzi, and to the committee, it is a thrill to be here and a pleasure to have the opportunity to speak to transforming what we usually think of as a liability from the dark side into an asset.

My name is Marcius Extavour. I am the Executive Director of NRG COSIA Carbon XPRIZE, which is a \$20 million global incentive

prize competition to drive break-through innovation in exactly that, recycle CO₂ into something more useful.

A really interesting part of that role is that it has allowed me to get a front row seat to not just energy innovation, but carbon management innovation in particular.

If there's one thing you take away from my remarks today is that carbontech, which is the piece of jargon I'm going to use to describe the basket of technologies that we can use to turn CO₂ into other materials and the materials themselves.

So that carbontech is a new technology space, it is an emerging space. It is quite young, but can be a promising tool to decarbonize our existing energy sector to help us fight climate change and to support long-term and sustainable economic growth.

As has been mentioned before, I'm going to echo some of the testimony that my colleagues here, that the State of Wyoming really is extremely well-positioned, not just because of the ITC, to lead in this area and already demonstrating leadership here.

Now carbon dioxide is usually thought of, if we think of it at all, as a colorless, odorless, invisible gas, maybe a greenhouse gas. However, we do not usually think about it as a valuable resource. In fact, it is and can be.

The global economy today is fundamentally based on carbon-based materials. You just have to look around the room to recognize that most of the stuff around us is made of carbon-based materials. The big idea here is that we can make some or maybe

even a huge fraction of those materials using abundant extra carbon dioxide.

Fertilizers, paints, fuels, building materials, carbon anode fibers is wide range of materials we can pursue.

The science of converting carbon dioxide into any material has been well known and characterized actually for several decades. We know how to do this. The science is pretty well understood. The questions at the cutting edge now are about engineering; scale up, business, finance, and policy.

Yes, we can improve on the science. However, there is also -- the field is now maturing and transitioning into broader questions. It is not can we do it, but how do we do it, and how do we do it in a way that makes economic sense, business sense, makes broader policy sense.

Carbontech, as I have mentioned, is a great opportunity to specifically generate revenue by harvesting a low value carbon dioxide feedstock. Carbon dioxide is -- there is basically no cost to emit it. There is a market price, but it is an incredibly low value feedstock.

Now, it is not free to convert it into other materials. It generally takes energy specifically. However, whereas we typically focus on the costs of carbon emissions, carbontech is an opportunity to also focus on the value and opportunity that can bring.

As mentioned before, this is an early stage technology area, and how do we unlock this?

Innovation. This is where the Carbon XPRIZE enters. The NRG COSIA Carbon XPRIZE was designed exactly to try to catalyze this type of innovation, and to drive the break-through in this space that can lead to benefits in this community, in the state, across the nation and the world.

The mission of XPRIZE is to try to help solve big problems that can impact and benefit all of humanity. In addition, certainly climate change, and the need to decarbon and transition and manage our energy systems and deal with our excess CO₂ falls into that category.

The Prize launched in 2015, and is about to conclude next spring, spring of 2021, where we hope to announce some of the winners from some of the demonstrations we see outside today.

After evaluating and demonstrating -- or, witnessing demonstrations of dozens of technologies from around the world, we have now narrowed the competition down to ten finalist companies, some of whom have the opportunity to test at the ITC.

The ITC was chosen specifically as the testing ground, in fact the XPRIZE was an early partner in helping it get stood up along with the leadership of Governor Mead, Governor Gordon, the legislature of Wyoming, you folks here on this committee, in fact the broader Campbell County and Wyoming community, without which none of this would be possible.

I just cannot stress enough how important the ITC and an opportunity to test a small industrial pilot is to the scale-up of innovation. Mr. Begger mentioned this earlier. You do not just come across facilities like this.

Carbontech, carbon recycling is not something you can build up in your garage. It is not two people with a PowerPoint slide. It is an industrial technology that requires safe operating, policy support, and business partnership.

This type of testing facility, which sort of lives between the university labs, research labs, and the commercial market, is a key piece of infrastructure. I really want to underscore that point. Facilities like ITC are unique in this space and absolutely crucial.

Now, I mentioned earlier that materials like concrete, gasoline, plastics, textiles, can all be made out of CO₂. Generally speaking, making products out of CO₂ can take a couple forms. We can make stuff we are already well familiar with, as I mentioned.

We can make fundamentally new materials that are barely in use today, but could be in broad use in the future, for instance, carbon fiber. Alternatively, we can make better or lower-carbon versions of material we already have.

I will give an example. You will see from the company called CT Concrete -- they will give us a tour a little bit later I know -- they make concrete. Concrete is not their innovation.

Their innovation is to use CO₂ to make concrete, and to make that concrete lighter, greener, stronger, stiffer than it otherwise might be. It is an example of a replacement material, a better version of something we already have. That just happens to be based on carbon.

Senator Enzi, you made a remark about jet fuel and liquid fuels earlier. That is another example. It is possible and people are already making jet fuel out of carbon dioxide. Is it better than existing jet? Jets fly the same, but the carbon intensity is much reduced.

Now we know that making industrial commodities out of CO₂ is a great opportunity. It is an economic and business and technology opportunity. However, there is something else I would like to highlight, and that is making consumer products. This is kind of an interesting, emerging niche of this space.

I brought a handful of items to show and tell, which I can speak to you about later. The interesting thing about consumer products is that it provides an opportunity to have a conversation with everyday people about the opportunity of what CO₂ conversion would mean.

It is one thing to say we can make jet fuel or make concrete. The average person is not really thinking about that in their daily lives, it is not relevant to our sort of our regular culture.

However, making items like this hand sanitizer, which is in front of me. How timely. This is actually made of recycled CO₂. This is something I think, especially at this moment, we can all relate to.

The other thing I think is really interesting about consumer products, of course need strong policy support, business support, and innovation of science and engineering. However, we also need

to support all of that conversation to permeate this conversation, this idea, this vision in the broader public.

I think the consumer goods are not going to absorb all the emissions coming out of Dry Fork stations; they are not going to solve the problem on their own, far from it. They are an interesting entry point into this conversation, for what is a pretty abstract and new technology area, one that I think can be quite powerful to help carbonize our energy sector.

With that, I would like to conclude. Thank you again for the opportunity to share these remarks. I look forward to questions and discussion.

[The prepared statement of Dr. Extavour follows:]

**Testimony Submitted to the United States Senate Committee on
Environment and Public Works
Energy and Environmental Innovation: Wyoming's Leadership in Using and
Storing Carbon Dioxide Emissions
Submitted by Dr. Marcius Extavour, Executive Director,
NRG COSIA Carbon XPRIZE
August 19, 2020**

Mister Chairman, members of the Committee, thank you for the opportunity to speak with you today about transforming carbon emissions from a liability into an asset. My name is Dr. Marcius Extavour, and I am the Executive Director of the NRG COSIA Carbon XPRIZE, a \$20M global incentive prize competition to drive breakthrough solutions in converting carbon dioxide into useful products and materials. This role has allowed me to become immersed in the energy and carbon management innovation space in particular.

The key point I would like to make today is that "carbontech" -- that is, technologies that can convert CO₂ into products and materials -- is an important emerging technology sector that the State of Wyoming, the United States and the world can make use of to reduce the carbon intensity of our energy sector, fight climate change, and support long term economically and environmentally sustainable growth. The State of Wyoming is very well positioned to help drive the development, commercialization, and deployment of these solutions.

Carbon dioxide is usually thought of as a colorless odorless and relatively inert gas, a pollutant, or a greenhouse gas. However, it is not usually thought of as a valuable resource. In fact, it is. Our global economy today is

fundamentally reliant on carbon-based materials, whether that is food, building materials, textiles, fuel, fertilizers and paints, and others. All of those materials can actually be manufactured using CO₂ as a basic feedstock, as an alternative to fossil hydrocarbons, especially oil and gas. The science of converting carbon dioxide into other more valuable materials has been well understood for decades.

The pathways usually involve biological conversion of CO₂, harnessing what plants already know how to do; mineral conversion of CO₂ into a more stable mineral, such as calcium carbonate, better known as chalk; or chemically, using electricity or heat to drive the conversion reaction. The science is well understood, and we know how to do it. The questions in carbontech today revolve more around engineering, business, and finance.

Carbontech presents an opportunity to generate revenue by harvesting a low-value carbon dioxide feedstock and transforming it into a high value product. This can actually create business opportunities out of reducing the carbon intensity of our energy and industrial sectors. The challenge is in making the technology efficient enough, and making materials that are valuable enough to be able to attract capital, drive down costs, and support scale-up and deployment. Innovation is the key that unlocks this puzzle.

The NRG COSIA Carbon XPRIZE is designed exactly to drive this kind of technology innovation. The mission of XPRIZE is focused on catalyzing solutions to problems that affect all of humanity, and whose solutions can create a future of abundance for all. We have created an opportunity for startups, university students, entrepreneurs and others from around the world to showcase their CO₂ conversion solutions, and to compete for a share of the \$20M prize. The prize launched in 2015, and is about to conclude in Spring of 2021, when we will announce the winners. After evaluating and testing dozens of technologies from around the world, we have narrowed down to 10 finalists. The ITC is the staging and testing ground for the finals of this competition, along with a parallel facility, the Alberta Carbon Conversion Technology Centre in Alberta, Canada.

To win the prize, teams must demonstrate a small industrial demonstration plant, using flue gas from a power station as their CO₂ supply. The ITC was designed to support exactly this kind of innovation, and the leadership of Governor Mead, Governor Gordon, and the Wyoming legislature have been instrumental in making this project a reality. I cannot stress enough how important the ITC has been and continues to be to the XPRIZE project. I also want to stress how incredibly audacious and demanding this challenge is -- to take a concept and scale it into a working industrial demonstration within just a few years. One of the Carbon XPRIZE finalists is operating at the ITC today, and I look forward to visiting with them after our proceedings today.

I mentioned earlier in my testimony that our economy is already reliant on carbon-based materials, like concrete, gasoline, plastic, synthetic textiles, and others. We do not typically think of these materials as carbon-based, but they are. Carbon-dioxide-based materials can take various forms. They can be fundamentally new materials that are barely in use today, like carbon nanotubes and carbon fiber. They can be better-performing versions of materials we are already familiar with, for instance lighter and stronger concrete, or biodegradable plastics. Alternatively, they can be exact replacements of materials we already use, the only difference being that they are made out of carbon dioxide instead of fossil hydrocarbons. Examples of this type include gasoline, diesel, jet fuel, methanol, formic acid, and many other industrial chemicals and materials.

We know that making industrial commodities like concrete, fuels and chemicals presents enormous business opportunities. A 2017 analysis by the independent nonprofit Carbon180 estimated a total addressable market of over \$1 trillion dollars for CO₂-based products, using only current and known technologies. A 2019 study in the journal Nature estimated break-even production costs of a range of CO₂-based materials, and their capacity to actually use up CO₂. The breakeven costs tend to be lower for lower-energy-intensity processes like making polymers, concrete, biochar, and methanol, and higher for higher-energy intensity materials like gasoline, diesel, and jet fuel.

The study also estimated that each of the individual material types they considered could each scale up to absorb 0.5 billion tons of CO₂ annually. Taken together, that means that CO₂ materials could reasonably be expected to absorb around 20% of total global CO₂ emissions, which is consistent with previous estimates. XPRIZE, ITC and many others are working on addressing the technical and economic barriers to realizing that possibility.

One of the most interesting and exciting developments in the space in the past two years is the emergence of consumer products, and consumer interest in products made out of CO₂. The emerging market for consumer products introduces a new and powerful social dimension, because it provides a way for regular people to participate in this space by buying everyday items that just happen to be made out of CO₂.

This is really a trend that emerged just in the last two years. It is important to note that the consumer products market is nowhere near large enough to absorb all the industrial CO₂ being produced today. Instead, the opportunity here is that consumer products are a way to engage a much broader segment of the population in the conversion and movement around the transition to lower carbon intensities and sustainable growth in our energy sector.

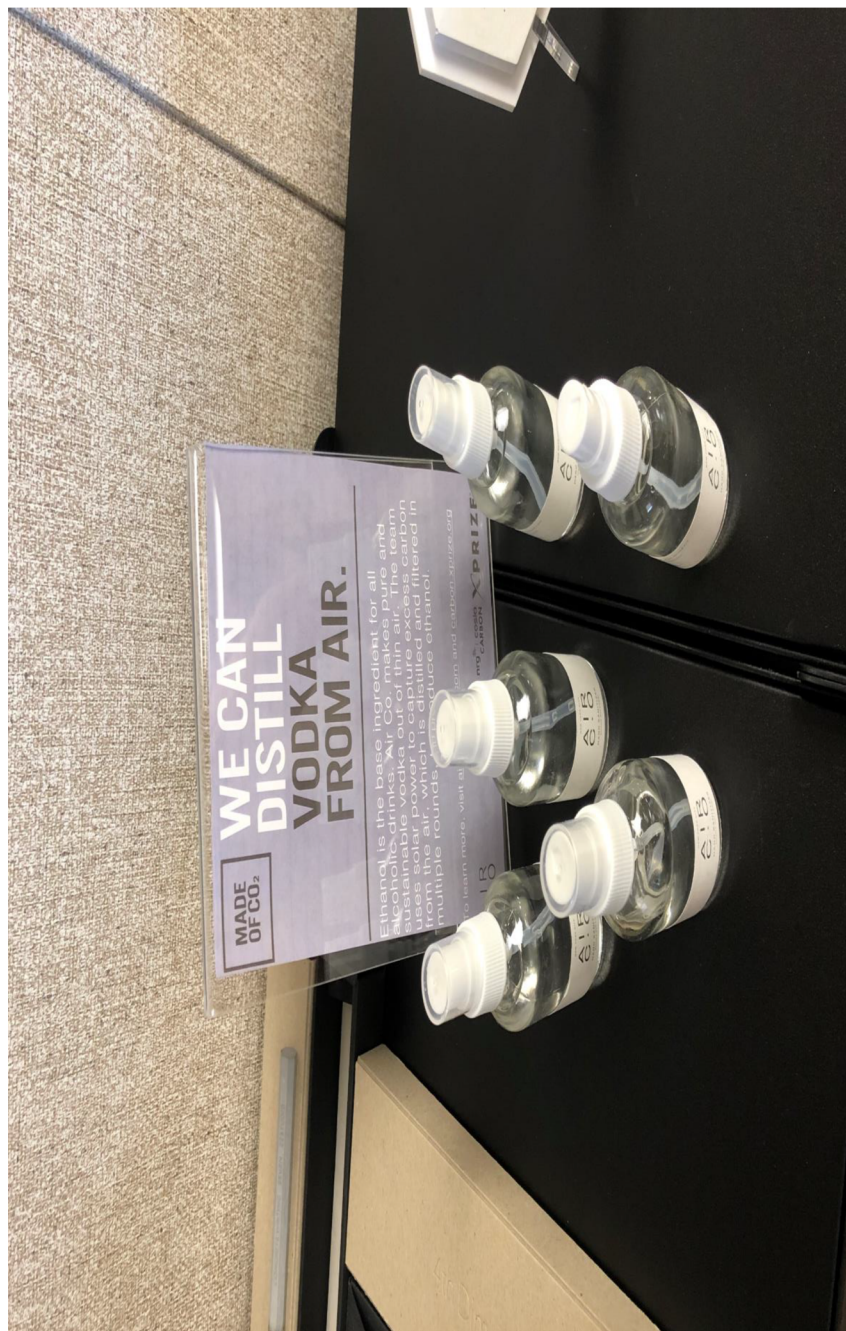
I very much appreciate the opportunity to speak with you today, and look forward to any questions and discussion. Facilities like the ITC are essential for developing and scaling up industrial technologies like the ones we are discussing today, and Wyoming has a terrific opportunity to lead in this space by leveraging the ITC.

(Extavour Exhibits follow)



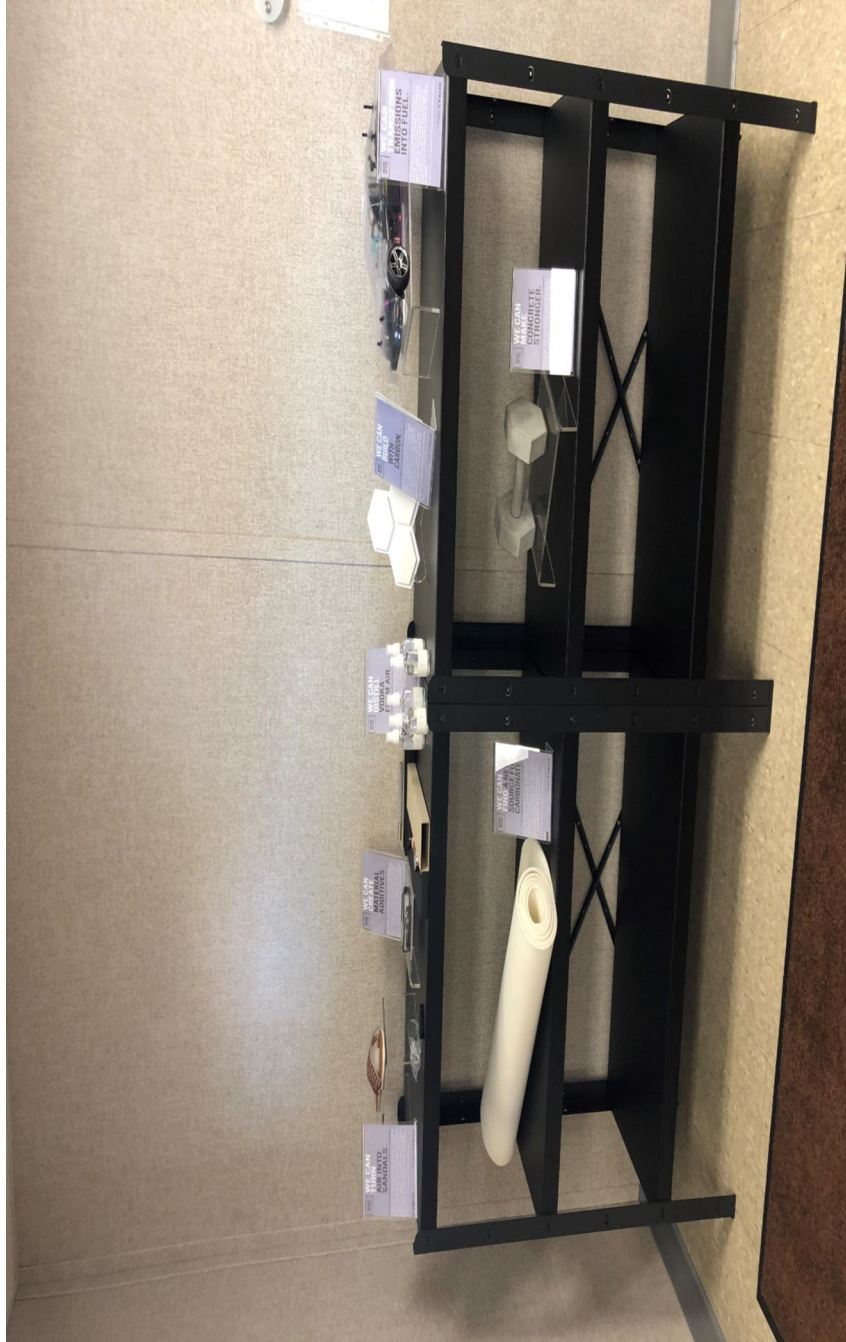


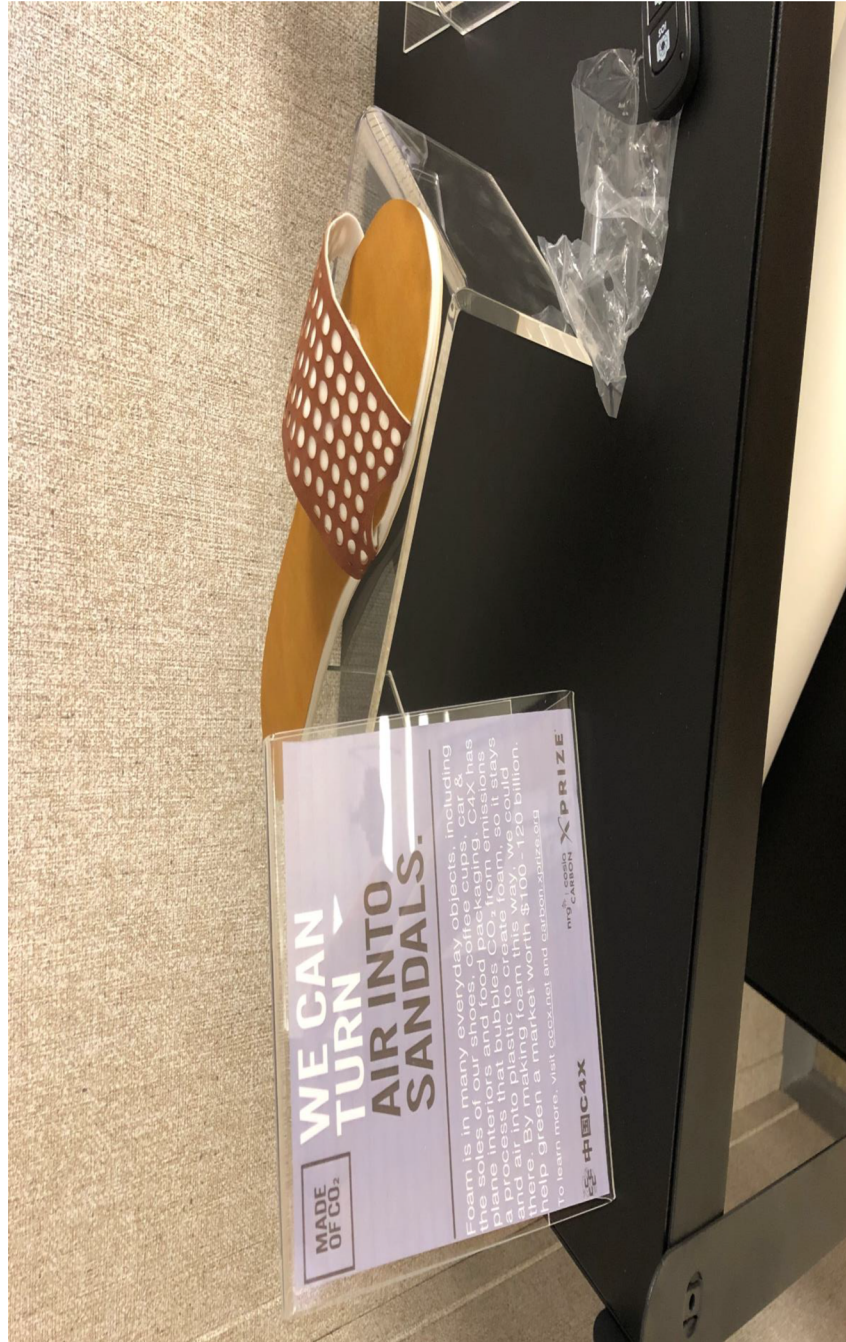












CHAIRMAN BARRASSO: Well, thank you to all.

Will start with a series of questions. I am going to pick up on something that you had said, but ask Holly the question, because you talked about Wyoming and what resources we have. I think, Holly, you started by saying, If you take only one thing away from this hearing, I was going to ask you to go back to that specific sentence.

However, it started with; Wyoming is the ideal place, if I got it right. So could you please, again, so that the press, they got the cameras going now, they need to hear this statement coming from you.

DR. KRUTKA: If there's one thing you take from my testimony, let it be that Wyoming is an ideal place to drive innovation and deployment of climate-focused technologies such as carbon capture use and storage, or CCUS, because the state boasts fast fundamental subsurface knowledge, world-class research programs, the ability to execute large demonstration projects, and the will to drive technology development with the necessary policy support that can ultimately result in commercialization.

CHAIRMAN BARRASSO: That is our marching orders from here, and to us, Wyoming is the ideal place.

DR. KRUTKA: Yes.

CHAIRMAN BARRASSO: Jason, let us start with you. The USE IT Act would fund research such as that is occurring right now. The test center, of the key criteria to receive funding under the USE IT As, we talked, is having partnership with the group academic, University of Wyoming, commercial development, government.

How important have strong private partnerships, public partnerships been insofar as developing this integrated test center?

MR. BEGGER: Mr. Chairman, I think the partnerships that we pulled together here is an ideal sort of model for what the USE IT Act does.

Earlier this year, the ITC, we received award from the international group, it was a carbon leadership Award, global award for innovative partnerships. The strength in that is, really comes down to, at the end of the day, we need partners, we need customers for these technologies that are going to be developed.

Therefore, having Basin Electric and the rural electric cooperatives and Tri-State and everyone on board, they can look at something and go, actually, that is something we would use, and we would commercialize and we would take forward.

Therefore, you know, without somebody who has going to take it to that next level, all you have is a really unique science experiment. Really, there is nothing wrong with those. If we do want to commercialize, you need to be working with the end users. I think that was a very important part of the partnership.

The other part is, I mean, you look at the power plant outside behind us. It was a \$1.4 billion asset. Clearly, they are very good at project management, procurement, you know, everything that it takes together to execute.

And by leveraging their expertise, you know, I mentioned how we were able to come in -- you know, this is a Wyoming thing that

we're pretty proud of -- really under budget and ahead of schedule.

That was -- not saying as the State of Wyoming we need to stand up our own team to do this. We are like, Hey, let us lean on the people that do this every day. Then they executed, you know, as promised.

CHAIRMAN BARRASSO: Dr. Extravours, just a couple things. One, just share -- I got the impression you are very optimistic about what we are doing here. I was going to ask you to expand on little bit on that, and what commercial break-throughs remain really to be seen here.

Can you discuss the competitive process that was used to select the finalists? I know there are five here, I think there are five also in Canada, and just how that all is working.

A Yes, certainly. I will take the second part first. That way that this -- first thing I will say is this. It is important to remember the purpose of the competition is to try to accelerate the pace of innovation in this space.

Jason mentioned earlier that, you know, it is quite complex. It takes something from an idea through to an industrial technology that can run at scale safely and effectively for years. Even shaving a little bit of time off that, money, as Jason alluded to earlier, is helpful from everyone.

The next prize is sort of a borderline, ludicrously extreme version of that. We set an extremely ambitious goal. Put it out to the world and say, who can solve this problem?

We are not sure who, but I bet someone can. A cash prize might help drive that.

The call is open to anyone in the world.

We have received dozens of submissions from around the world. We have an independent panel of judges; Dr. Krutka would be one of them, actually.

And they have down-selected by looking at performance data and evaluating the data that the team submit down to ten finalists, five as mentioned testing here, and five at a similar facility also built around the same time called Alberta Carbon Conversion Technology Center.

Key difference being it is fed by a natural gas plant, not a coal plant.

The teams are evaluated in three basic criteria. One, their economics. Does this process look like to become a sustainable business?

Two, environmental sustainability, which really boils down to, are you using more CO₂ than you produce? You can make hand sanitizer and produce CO₂ in doing it. We are interested in actually reducing CO₂ in producing it.

Third, engineering variables. Are you more efficient than your peers or not, which usually boils down to how efficiently, how little energy you can use to execute this process.

My optimism, I would call it data-driven optimism. This is a huge problem, but it is also an opportunity. I will say that there is a market opportunity and a technology opportunity.

The market opportunity is that, I will reference a figure here. Independent not-for-profit called Carbon 180 did a market study. All right. What are all these CO₂ materials, what are we talking about, how can we get into these markets.

Just looking at known technologies today and known material markets actually circa 2017, they estimated that the total addressable market is \$1 trillion. That is a small number in the context of the global economy. It is a huge number in the context of making stuff out of CO₂, which is a still a relatively young industry. The market is there. I am optimistic about that.

On the science and technology side, I am optimistic, like, specifically the ability to produce existing materials in a cheaper and lower-energy way. Lower, lower energy.

And that -- to get into the science, that really has to do with sort of how little energy we can get away with using, but also in producing new materials that aren't quite yet abundant in the marketplace but could be.

Things like proteins made of CO₂. A bit of a weird concept, but that could be a future. In addition, things like carbon fiber, which is a niche. Expensive material used today, projections show it could be a much broadly cheaper, probably use cheaper material in the future.

The ability to make even a small a fraction of those materials using carbon dioxide emissions is a huge opportunity, which makes me optimistic.

CHAIRMAN BARRASSO: You want to ask more questions?

SENATOR ENZI: Thanks, John. I really appreciate the testimony of all of you again.

One of the things I like about a hearing is usually we can have the opportunity to, even after the hearing is over, we can ask more questions. I am an accountant, so I try not to be too technical in my questions. Just put the audience to sleep. I am not very good at questions anyway.

All right. Jason I will, start with you. Because of the pandemic, of course, there is a tremendous constraint on federal government, local government, and state government. One of the things we are discovering, of course, is that if the economy is not there, there is no money.

How can we ensure that every dollar that is invested in this carbon capture and research development goes as far as possible?

MR. JASON: Senator, that's a really, really good point. One of the things that we have really prioritized is these partnerships, you know. You think about the Wyoming Energy Authority coming together. That has members from the School of Energy Resources, the Enhanced Oil Recovery Institute, the business council, and those types of things.

You know, what we really want to do is make sure that we are all talking and, you know, sharing. The worst thing we can do is duplicate what somebody else is working on. So, looking at ways to be as efficient as possible.

That extends to our relationships, you know, on the national and international level. For example, the organization

called the International Carbon Capture Test Center Network. There is 14 facilities globally that are working in this space.

We share best practices to -- sometimes we share information about, you know, bad actors that are -- you know, that are trying to, you know, play in the space. Therefore, you know no reason to reinvent the wheel if people have already learned those lessons. There is a huge focus on that.

You know, as an accountant, one of the things that we've been able to do and work with the Department of Energy, is the funding for this facility to build, you know, the bricks and mortar that we have here today, is \$15 million from the state of Wyoming, \$5 million from

Tri-State, and \$1 million from NRECA.

Well, that is all non-federal money. So if it is accounted for and applied the right way in the same accounting language that the Department of Energy uses, it can be used as nonfederal cost-share on these projects.

By tweaking our internal accounting systems, we basically found \$21 million to leverage against additional federal opportunities.

So we're really thinking about, okay, this is what we have, given the economic situation federally, you know, in the state and everything else, going back and asking for, you know, \$50 million probably isn't in the cards right now. So what can we do to stretch things the best that we can?

The last area, and along those lines, is kind of a -- it is also kind of a Wyoming thing. You do not need to build a Rolls-

Royce when a pickup truck will work. You know, you look at this facility here. It is a modular facility that we were able to procure from, you know, oil services that were kind of moving on. We were able to make it ADA compliant. It meets every standard, but it was not a, you know, \$20 million, you know, facility that had all the bells and whistles.

Not to say we do not want to get there, but what we want to do is kind of bit-by-bit, piece by piece, you know. This Company A is leaving behind their steam boiler. Hey, can we for a small fee take it over and just build capacity that way?

Therefore, we are really mindful about stretching the dollar the best, the furthest we can.

SENATOR ENZI: Thank you. Dr. Krutka, you mentioned syngas at half the cost. Can you go into a little bit more detail on how that -- what that is, how that works? I am not a chemist.

DR. KRUTKA: Yeah. Sure. So thank you for the question, Senator Enzi. So syngas, what we -- we can, from coal -- let us see.

We have a thermo-chemical process that is designed to create unique products from coal. Most of the carbon is locked up in the coal, but some of it comes out in the form of CO₂.

Therefore, there is lots of options. You could do something like what we are talking about, the XPRIZE and use it. You could store it. I want to give a shout out to the head of our CEGR group, Mr. Scott Klonen, over there.

They are setting -- they the CarbonSAFE project right outside Dry Forks. You can store it, or we have another potential

use for it, which would be combine that CO₂ with natural gas. Without getting too into the chemistry, what comes out of that, we have a catalyst that helps facilitate that reaction.

What you get out of that is carbon monoxide and hydrogen.

It is the hydrogen that would be half the cost of conventional hydrogen production technologies today. The way you make them today is with C methane reforming and natural gas.

When you get syngas, which again carbon monoxide and hydrogen, you can do all kinds of things. You can make plastics; you can make anything that is made from carbon and hydrogen molecules.

One of the things we could also do is further treat that gas to have -- to separate the hydrogen. Then you have a clean fuel. Again, you can use the CO₂, or you can store it, or you can use it for other things. However -- and then you would have hydrogen as a zero-carbon or low-carbon fuel source as well.

SENATOR ENZI: Thank you.

DR. KRUTKA: I will draw a picture afterwards.

SENATOR ENZI: Ask you more about that then.

Recoverable oil there is still in the ground if you want to go after it. Comment on that?

DR. KRUTKA: The amount of oil?

SENATOR ENZI: Yes. The original drilling, as I understand, it gets 20 percent.

DR. KRUTKA: Right. Yes. There is a tremendous amount of work that can be done on this -- in this area. Even -- you know, you mentioned that Center of Innovation for Flow through Porous Media,

they are focused on driving innovation to just squeeze more oil -- understanding the fundamentals, so that they could squeeze more oil out of conventional and unconventional reservoirs.

I mean, there is also Enhanced Oil Recovery.

There is a number of technologies. However, you are right, they are so -- the vast majority of oil is left in the ground. And you know, in a world where there may be less permits coming out, you really need to -- and less drilling operations, we need to squeeze every last drop out of our existing operation.

SENATOR ENZI: Funded without federal dollars?

DR. KRUTKA: I believe -- I mean they -- yes. The highway research facility was funded by the State of Wyoming and corporate sponsors. They do -- I believe they are a Sub ORD on a federal grant now. However, that has nothing to do with the construction of the facility and the initial operations.

SENATOR ENZI: Thank you.

Dr. Extavour, I am glad we are looking at some other uses for carbon. I am reminded of a Dilbert cartoon. Dilbert is given the assignment of eliminating CO₂. He says to the boss "You do know that we will not be able to grow any plants then?" The boss says, "So, we won't eat vegetables."

Well, the next day Dilbert has the machine that will do that. However, he warns the boss, he says: Now, the really important part of this is, if you do not turn it off about three days a week, people will die.

Then the next frame you see the janitor going over to this machine saying: Woops, this is unplugged.

So, glad that you are coming up with some valuable resources and encouraging people to come up with innovation. I know that they have challenged people with an XPRIZE to be able to pedal a bicycle across the English Channel. Sure enough, somebody did it. Therefore, challenge the American people is what we need. However, I think this XPRIZE competition demonstrates a variety of applications.

How would you explain to the typical American consumer about the way this research would affect them? The kids in school?

MR. EX: Thank you for that question.

First, I will say I truly appreciate you bringing Dilbert into the conversation. I prepared for this hearing by reviewing my back catalog of Dilbert cartoons. I think I have actually seen that comic.

It is a funny thing when we talk about energy transition or even using CO₂ materials, because in some way, you know, in this place we are privilege to have, for instance, electricity, it is basically on all the time. Somewhat surprising if you flip a switch and the light does not come on in this part of the world.

When we talk about energy transition, we are sort of talking about replacing the back end without necessarily a lot of disruption for the user.

SENATOR ENZI: I guess what I was going for is more of the products that can be made. We can switch from the polyester that is already out of date to carbon.

DR. EXTAVOUR: Exactly. I think there is huge opportunity here. For some people it will be very inspiring. Just let us say, this polyester shirt was made out of recycled carbon, this one was made out of virgin oil and gas, let us say, that was drilled.

Some people just are not going to care. They are just, you know, does the shirt fit, does it have the right color, do I like it or not. That is totally fine.

There are some consumers studies show that will respond well to, Oh, this is a little bit more sustainable, or, Oh, this is made from material right in my home state, or, Oh, I really like that it's made out of CO₂ materials. However, that is probably a minority of people.

I think the thing that is really going to catch people is what a lot of people that are in the market are trying to do is produce something better. This polyester shirt, to give the example, will last longer, or hold its color better, or be cheaper because it is made of greenstock.

These materials are not really there today. However, I think the promise of the opportunity is to get there. So I think for the average person will be -- or let us say a consumer of a commodity, chemical, cheaper, better, or lower CO₂ footprint or all three.

SENATOR ENZI: Thank you. I will turn it back to you.

CHAIRMAN BARRASSO: Holly, you mentioned permits and underground storage of carbon dioxide requires permitting under the federal Safe Drinking Water Act.

Wyoming recently applied for primacy so that we can issue the permits ourselves rather than having to go back to Washington

and the U.S. Environmental Protection Agency. With Wyoming's own expertise, the state is expected to process permits I believe in a more efficient way than regulators at the EPA could.

So how important is timely permitting to the success of some of these underground storage projects?

DR. KRUTKA: Thank you, Mr. Chairman. While timely permitting is really critical, the priority has to be to ensure that the storage risks are, and the storage projects are conducted safely and securely to minimize potential risk to human health and the environment. However, we believe that here in Wyoming we can accomplish both.

It is vital for project developers that permits are not unduly delayed. Regulators with the best knowledge of local geology are here.

That means the Wyoming Department of Environmental Quality should be able to process the permits efficiently, while maintaining the safety and security of CO₂ storage, and launch a widespread CCUS industry.

Time is of the essence for several reasons. Perhaps most importantly, the clock is running on the amended section of 45Q tax credits, the world's first incentive of this type to support CCUS.

Claiming these credits requires construction to start before 2024. We need rapid deployment of that technology to reduce the costs associated with the technology and a phenomenon that has been demonstrated in countless clean energy technologies before.

Therefore, for many, many different reasons, permitting time is really critical.

CHAIRMAN BARRASSO: Jason, following up with what she just said about the 45Q tax credits and that extension and expansion commercializing more carbon projects, how would the USE IT Act help complement the 45Q?

MR. BEGGER: Mr. Chairman, you know, in order for, I guess, simple economics for any project, you need to have a margin. You know, for these early stage technologies, you know, that involves two things.

You know, one is, can you increase the profitability or bring down the costs? You know, looking at what has happened in the renewable sector, you can say that has been a great success.

You know, the various tax credits to -- you know, to increase the profitability, coupled with the research that's been going on, and that needs to be -- or, could be replicated here in the carbon tax sector where you've got a tax credit like 45Q that provides a stable revenue stream to get us through these early stages where, at the same time, the resources made available through the USE IT Act provide some research dollars, you know, to try to bring down those costs, and hopefully improve the margin.

Can get to the point where, at some point they are just no longer needed. You know, we have kicked them out of the nest, so to speak.

CHAIRMAN BARRASSO: Dr. Extavour, the USE IT Act has a competitive price program, one spurring more research into direct air capture.

Bill Gates has said he does not want to get to a zero carbon footprint; he wants that machine, Mike, which you talked about, because he said he wants to remove from the atmosphere any carbon dioxide he has put in since Microsoft began in 1978. I think he's committed, he said he would commit \$1 billion of his own money to that.

Can you discuss that whole concept and what you see coming down the line?

DR. EXTAVOUR: Yes, certainly. I think Bill Gates has it right. Microsoft famously made a commitment to remove the equivalency of emissions that company has produced. They are a software company, so they are not such an emissions maker.

On the other hand, no other company has made that commitment, period. That is just here in the last few months here.

I think what he's describing is something we fully agree with at XPRIZE. If you stack up all of our CO₂ sources, some of them are easier to curtail than others. The way this is going to go is, as we curtail emissions is, it is going to -- you know, we should start with the easy stuff. Then it is going to get a little harder, and a little harder, which means a little bit more and more expensive.

At some point, we will cross a threshold where it is cheaper and more effective to keep those sources online, and maybe just build another source that can actually sort of reduce the CO₂ emissions.

Therefore, I think what Mr. Gates is thinking about is trying to focus on innovations, specifically the, I am going to go and get it, and remove past CO₂ emissions.

I will share an analogy, if you do not mind.

This is Klaus Lackner's from Arizona State analogy. It is akin to a trash cleanup problem. There is a pile of trash in a public park. Well, first thing you should do is not add more to the pile. That is reducing our existing emissions.

Even if you turn your emissions to zero, or greatly reduce them, you still have a trash pile in the park. Someone is still going to go pick it up. We still have excess CO₂ emissions that we are going to want to curtail. We are going to want to reduce what we can today. However, going forward, we also may want to actually pull some CO₂ emissions back out of the air or the atmosphere.

CHAIRMAN BARRASSO: He points out that the technology that can be developed places like here, could that be used worldwide, India, China, and other locations --

DR. EXTAVOUR: Absolutely.

CHAIRMAN BARRASSO: -- that don't have the same commitment that we do here in Wyoming?

DR. EXTAVOUR: There is a tremendous opportunity not just for the State of Wyoming but the broader United States to be the leader in this technology area, and be the nation that can develop it and export it.

We -- we are confident that there will be demand for this technology. We are already seeing some demand expressed by

companies like Microsoft and a handful of others. At XPRIZE, we have a competition now for CO₂ conversion. Thrilled to be able to have the ITC as a partner in that. We hope in the future to launch a prize for exactly this, direct air capture and other means of remediating CO₂, whether it is from agricultural land management, building a machine that sucks it out of the air, or any other method. However, I think you are exactly on the right track with that, and we support Mr. Gates in that.

CHAIRMAN BARRASSO: Additional questions?

SENATOR ENZI: Well, it is one for Mr. Begger. In your comments, you said something about having to go to Norway to scale up. What --

-- I do not understand that.

MR. JASON: So Senator, right now, if you want to test a project of a certain size -- so, in the United States, kind of the typical scale-up -- and I have got a great slide that shows a very small scale of a carbon capture facility in Columbia University. Looks like a pressure cooker.

Then sort of the next scale up is a skid-based system, which you will see here today. Then the next level, sort of a pilot scale. Hopefully a commercial scale.

However, most utilities need to see something at the 10- to 20-megawatt equivalent to feel comfortable that systems integration and the scale-up actually are a reality.

So when these really small projects, they are a couple kilowatts. Therefore, if you go to the National Carbon Capture

Center in Wilsonville, Alabama, which is a DOE-funded facility, about the largest project they can host is about 1.5 megawatts.

So if you're ready to take that next step to do a 10- or 20-megawatt size project, you either need to do a one-off deal with a power plant -- and that has happened at times, you know. If you are a really well-known developer like, you know, GE or Mitsubishi or somebody like that, you have a lot of institutional reputation where you can call Southern Company or Excel.

However, if you are a little developer calling, like, Hey, can I cut a hole in your billion-dollar power plant, they are going to tell you to go away. So, there is a facility in Norway called Mongstad that is -- it is a natural gas facility, but it has -- it is similar to the ITC in ways.

It is a wonderful facility. However, it is the only facility of that size globally where you can sort of plug and play those larger technologies.

So we -- over the years, we have had a number of DOE U.S.-based technologies that have had to go to Norway to test simply because they did not have infrastructure in the U.S.

So we've gotten positive response from Norway -- or, excuse me, from the Department of Energy when they come out here and look at this site, going -- there's someone specifically who has told me, Every time I go to Norway and I'm at -- you know, going out and I have to pay \$18 for a cheeseburger, it just boils my blood.

Because I know, all of these tenants and all of these taxpayer dollars are paying \$18 for a cheeseburger. Therefore, I

can come to Wyoming and, you know, spend \$6 for a cheeseburger. Therefore, I think they are really excited to see, you know, how the XPRIZE tenants work. You know, TDA is our first one out here. To sort of see, okay, do these people have this under control? Are they able to host some of these larger projects with the goal that at some point they go, Yeah, we are sending all of our DOE stuff to Wyoming and not Norway.

SENATOR ENZI: And Dr. Krutka, I'm happy to see the partnership between the Department of Energy and the University of Wyoming on the CarbonSAFE program, and happy to have a leader in the Chairman Barrasso to the Department of Energy in support of that partnership.

Can you talk about the importance of this kind of research in helping scale-up commercial technology?

DR. KRUTKA: Right. So thank you, Senator Enzi, for that question.

I think first of all we are very, very proud of the Wyoming CarbonSAFE project. We also have -- we have a great slide showing all the partners in and around the state of Wyoming and beyond that are participating in that project.

Of course, the most important partner is the Department of Energy. Especially for CO₂ storage, it is critical that we have these large DOE projects moving forward.

As I said, there is five around the country. We feel very positive about the Wyoming CarbonSAFE project for many different reasons. As I said, one of them is that we have the subsurface

knowledge and properties that are going to likely make that successful.

However, one of the things that you should know about working with the Department of Energy and doing a true research and development project is that we are able to really study things on a deep level. We are able to look at a lot of details that need to be understood before we can launch CO₂ storage on a large scale, to give the government or regulators the confidence that they can allow this technology before permitting.

The other thing we are trying to do with that project is make a glide path. Therefore, as industry picks up that technology and starts to deploy it more commercially, more widespread, you know, we want to make that path easier, especially here in Wyoming where we are focused.

Therefore, we are doing things like writing model contracts, right, which you would not do if you were just binding it with a single corporate partner. We are going to be able to support entities wanting to deploy carbon storage projects in Wyoming in the future as a result of that CarbonSAFE project.

SENATOR ENZI: Thank you. I am encouraged by hearing. Just add a final comment, I do remember that General Electric was going to do the project in Wyoming several years ago, and they canceled it.

When we got ahold of them to find out why, they said with this de-emphasis, or actually criminalizing coal, who would we ever sell our technology to?

Well, I'm glad that we have this team of people across the United States, across Wyoming, that are trying to de-criminalize coal and show that it is essential to, in a lot of different ways, to our lives. So thank you for your testimony.

CHAIRMAN BARRASSO: Following up, just in terms of ways to store carbon dioxide, research being done with seismic testing that's occurring just a short distance from here, are there specific policies that you would recommend that Congress focus on to advance some large scale carbon storage?

DR. KRUTKA: Yeah. Thank you, Mr. Chairman. Thank you for all your past support of those policies. SER Center for Energy Regulation of Policy Analysis believes that federal policy regarding management of long-term storage and liability of CO₂ is vital.

In addition, incentives remain critically important to ensure that CCUS will be widely deployed. From our perspective, R&D funding in commercial deployment incentives go hand in hand to reduce the costs of deploying CCUS now and long into the future.

For example, of course there is the amended 45Q section -- or, section 45Q tax credit. It is vitally important. It spurred interest so much since it was modified, but it should be extended, especially given the delay with green policing guidance. Again, thank you for your pressure to help get that guidance release.

Fixing other CCUS related incentives, for example, 48A, that would unlock funds that are already authorized by Congress. Of course, we have already mentioned the USE IT Act, which would help

us advance things like direct air capture, but also get CO2 sources to sync. So, from the producer to the storage location.

Therefore, beyond that, you know, there is a number of policies. I will say clean energy technologies need more than one incentive to move forward.

Fully agree with that, and that is why we are observers of the Carbon Capture Coalition, and members of the Carbon Utilization Research Council. Fully endorse the policies that they have been pushing forward as well.

CHAIRMAN BARRASSO: Turn to Jason right here. The Dry Fork Station is an example of a site where it is possible to use the storage capture right nearby for carbon dioxide.

Nevertheless, other sites require pipelines to get from site one to two, to transport it to where it is stored. So how important is a robust carbon dioxide pipeline network in order to really maximize the value of the volume that we can capture and use and store in Wyoming?

MR. BEGGER: Mr. Chairman, it is going to be critical, you know. In some cases, I have heard people say it is going to be almost equal to the build-out of the existing oil and gas pipeline network.

You know, maybe the simplest way to think about it is, we are going to need a new national sort of interstate highway system for CO2 pipelines. You know, it's kind of one of those chicken and egg arguments, where you don't want to build it until you know you have users and producers on one end. However, you cannot really identify those until somebody has built it.

You know, looking at how we are going to build them, what size they should be, where they should be located, are all critically important.

You know, one thing we all recognize in Wyoming, and they are somewhat baffled somewhat that other states don't recognize that, when you look at the land ownership issues in Wyoming, you know, you're not going to throw a baseball across the highway without probably a NEPA analysis.

Therefore, what can we do through things like our corridor initiatives, to identify the right places to put these things, the right size that they should be, and where they really need to be going?

It is a critical link to all of this that probably is not discussed nearly enough.

CHAIRMAN BARRASSO: Mike, if you do not have any other questions, I was just going to ask the three panelists to see if they had anything else.

I saw Dr. Extavour making notes and others have as well. See if there was anything, we did not ask that they might want to share with us.

DR. EXTAVOUR: Thanks very much for that, Mr. Chairman. I will be brief. I just love to lend my voice of support to the USE IT Act. I applaud your effort. Thank you very much for nudging the secretary of the treasury for that guidance.

To be blunt, it cannot come soon enough. To give a practical example of I think how 45Q specifically can impact this space, we

are going to have a look at some sort of early project developers outside of the ITC.

They are projects that are probably a little too small to take advantage of the tax credit.

They also probably do not really have a tax liability to offset. However, what 45Q has done is entered -- has created a new class of people, which we need in the sector, which is the project developers.

They are not necessarily the power stations. They are not the technology developers. They are the dispassionate people in the middle that say, Okay, I know how to scale up projects. I can combine three technologies and make a large project, and we can do the accounting and that project will benefit from 45Q.

I have to know some of those folks over the last couple of years since 45Q's passage.

Unlocking the guidance will unlock their ability to help scale this technology, which is probably a path to scale these types of technologies.

Thank you.

DR. KRUTKA: First, I just wanted to thank you for having me here today. In addition, it has been an honor to be on a panel with Dr. Extavour and Mr. Begger. I really appreciate you bringing your attention to the subject.

I guess I would just follow up on my comment that you had me read again, and just say, you know, we have been very focused on CCUS. It is a critically important technology for Wyoming and beyond.

The thing I would add is I also think Wyoming has so much potential to be a leader in other energy technologies as well. So, like I mentioned, coal to products, you know, we have centuries of reliable, secure coal that is one of the most affordable, if not the most affordable, fuel in the world right here. We are probably sitting on some right now.

Therefore, I do not want to dismiss that in the research programs that are trying to find uses for that, as well as we are working on new types of power plants. I mean, the sky is the limit. I am just so, so excited to be here.

I hope that we all continue to see Wyoming as a leader in research for all different types of technologies. Thank you for your time.

MR. BEGGER: Mr. Chairman, again, I really appreciate the chance to speak with you again in front of your committee, and would always like to open the doors to anyone in D.C. and the EPW to come out here.

I think one of the things that people need to see is this power plant right behind us, because this is what a modern new power plant can look like and does look like.

At a time when you are seeing rolling blackouts in California, it's, you know, coal.

There is a role for that. There is a need for that.

And all the things that we're working on today are ways to ensure that we can still deliver that low-cost reliable power in ways that meet sort of a new societal standard for cleaning -- or, for clean energy.

You know, one of the things as we were building out sort of the, I guess, the business development aspects of the ITC, you know, trying to attract these people in, we started saying, Well, if you're coming in here, you should really talk of SER, tour the power plant and EORI, and all of these things.

One thing we realized after going through all that stuff is that, Wyoming is so perfectly and uniquely suited for a lot of reasons. You know, the world-class facility, the ITC, the only one of its kind in the U.S.

You know, the expertise at the School of Energy Resource, Department of Environmental Quality, you know, the great geology that we have, you know, I mean, that's something that a lot of places can't offer that. You know, a quarter-mile to the south here, we have a 10,000-foot well that looks like it's going to be awesomely suited for long-term geologic storage.

Then also scattered around us are a number of potential fields for enhanced oil recovery or production and those types of things.

Lastly, probably the most important thing is this license to operate that we have within the state. That means we have political acceptance. You know, we see the folks in the room today in the audience. You know, clearly, there is support from our elected officials to make this stuff happen, but also public support.

You know, we have been doing EOR and carbon management for years in the state of Wyoming. Therefore, there is that broad

public support. One of the tenants that is hopefully be coming up here, they are from the Bay Area in California.

He told me, he goes, the one thing that we really like about is, you guys always find a way to get to yes. You know, we could not manage trying to permit this in California. We would get a hundred reasons why this will not work; as opposed to you will sit down with you and go,

Okay, here is the Clean Air Act; here is the Safe Water Drinking Act. Here are all the things that we need to do. Here is the glide path to get to yes. If you do these ten things, we can do this right here.

Therefore, people are thrilled that, you know, as the state government, we are not throwing up roadblocks. We are trying to help them get there.

You know, there is a lot of great things about what is happening in Wyoming. We think we are the perfect place to do that, and just sort of just the tip of the iceberg on what the stuff could look like.

CHAIRMAN BARRASSO: Anything else from your notes?

I am just so grateful for all of you on the panel and for everyone who has attended. As you know, those that have testified in the past, there may be additional questions, written questions submitted. Been texting with Senator Carper from Delaware, who is the ranking member of the committee, is sorry to not be able to join us today. He had to be in Delaware to help nominate one of his old colleagues from the Senate last night. Therefore, he had to choose.

I said, you missed the boat. You were on national TV, but you could have been in Gillette with us.

He will come another day to examine, explore, visit, and learn. He has been very interested. This has been a bipartisan effort, as you know, in the Senate, working together. These things are coming out of the committee 21 to nothing. There are conservative members of the committee and we have already seen it.

Therefore, there is a unified effort to make this work. We know we need all of the energy, the globe needs all of the energy. We want to make energy as clean as we can, as fast as we can, and new ways that do not raise costs for consumers. Getting back to, Wyoming is the ideal place.

So with that, I want to thank the witnesses, thank everyone else who has joined us, and with that, the hearing is adjourned.

[Whereupon, at 11:18 a.m., the hearing was adjourned.]

[Additional material submitted for the record follows:]

**Testimony Submitted to the United States Senate Committee on
Environment and Public Works**

**Energy and Environmental Innovation: Wyoming's
Leadership in Using and Storing Carbon Dioxide Emissions**

**Submitted by Cindy A. Cane, Chief Officer,
Enchant Energy Corporation
August 19, 2020**

Chairman Barrasso, Ranking Member Carper, and Members of the Committee:

Enchant Energy Corporation (Enchant) is pleased to submit written testimony on energy and environmental innovation to the Senate Environment and Public Works Committee. My name is Cindy Crane and I serve as the chairwoman of the Energy Resources Council, which guides the School of Energy Resources at the University of Wyoming. I am also the Chief Executive Officer of Enchant Energy Corporation.

Enchant is a New Mexico-based company whose mission is to develop carbon capture and storage (CCS) projects and carbon capture utilization and storage

(CCUS) projects. Enchant is currently the developer of the largest carbon capture project in the world, a project that will require \$1.5 billion to complete. Enchant was formed by a group of veteran energy investors for the purpose of acquiring the 847 megawatt (MW) coal-fired San Juan Generating Station (SJGS), in San Juan County, New Mexico, originally slated to close in 2022, and to retrofit the plant with CCUS technology. Enchant is in a public private partnership (P3) with the City of Farmington, New Mexico and together we have acquired the rights to own the San Juan Generating Station. We are in advanced stages of development of the CCUS project and expect to start its construction in mid- 2021. This effort will allow us to extend the life of the coal plant using carbon capture, while fully complying with all of the federal and state environmental requirements, including compliance with the New Mexico carbon reduction requirements being implemented under the state's Energy Transition Act (ETA) that became effective in 2019.

The ETA requires we halve the current carbon intensity from 2,200 pounds of carbon dioxide per megawatt-hour (MWh) to 1,100 CO₂ pounds / MWh. In fact, as we have publicly shown in a Sargent & Lundy study, the carbon capture technology we plan to deploy will capture more than 90 percent of the total carbon dioxide forecasted to be emitted by the generating station. Our analysis was bolstered by the recent U.S. Department of Energy (DOE) study that showed that the world's largest demonstration project, Petra Nova, owned by NRG, captured 92.4% of the carbon dioxide emissions over its three-year study period. Utilizing carbon-capture technology, we will be able to reduce carbon intensity from 2,200 pounds of carbon dioxide per MWh down to approximately 250 pounds of carbon dioxide per MWh, which is far lower than current natural gas generating technology.

As the Committee members may know, CCUS is a key technology for addressing climate change while preserving jobs and economic development in hard-hit communities in the Western United States. This technology allows for the capture of climate-damaging CO₂ from the emissions of power plants and permanently stores them in sub-surface geologic formations, thereby preventing an increase in CO₂ in the atmosphere. Utilization of CCUS to preserve jobs and economic development is particularly important in New Mexico's Four Corners Region, where the bulk of electricity producing industries in or near the Navajo Nation have closed or are slated to close resulting in thousands of jobs lost and serious adverse impacts to local revenues. The technology has been advanced by the U.S. Department of Energy (DOE) over the past three Administrations and is supported by many leading environmental organizations, and labor unions. Our project is a full union job with a project labor agreement.

Enchant believes that its work in New Mexico can be a model for future projects in Wyoming, the United States, and North America. I would like to share with the Committee what we have learned so far from our work to date and also discuss ways in which the Committee and Congress can further help the carbon capture industry by creating more robust incentives and funding streams for the development of new projects and innovative carbon capture technologies.

Carbon Capture Policy Benefits

Baseload, decarbonized electricity generation is vital for maintaining our reliable and inexpensive grid power. This generation capacity is especially important now that the market is building larger quantities of wind and solar power. Moreover, there exists no battery storage technology in the world today at the scale of the San Juan Generating Station, 847 MW. Currently, battery technology is at a relatively early stage of development and integration in the electric grid; it is expensive to build and can be unreliable to operate. Since at this time the United States is generally not building new baseload generation, dispatchable hydroelectricity or nuclear

generation units, legacy coal plants plus carbon capture is key components for balancing the grid that has significant capacity derived from wind and solar. In our view, CCUS is a far superior way toward the goal of "keeping the lights on" in a reliable and affordable way while still addressing climate change using a mix of renewable and fossil-fuel-derived energy sources.

Wind and solar resources today are insufficient to meet demand. Meanwhile, carbon capture facilities are designed to help substantially reduce carbon dioxide, while providing reliable, dispatchable electricity. Coal generation plus carbon capture provides the indispensable technology for grid stability, job retention and creation, and the reduction of the United States' output of carbon dioxide.

It is important that Congress enhance its incentives for carbon capture. The DOE has been an important policy leader by providing federal cooperative funding to companies like Enchant so we can innovate and demonstrate the large-scale economic viability of carbon capture. In addition, wise federal policy, particularly the 45Q carbon capture tax credit, can incentivize Enchant and other developers to employ thousands upon thousands of new workers and keep employed tens of thousands of existing power plant workers and coal miners. These policies also can reduce emissions and keep traditional baseload facilities in operation that support their communities with jobs and a robust tax base.

Enchant Project Background

Enchant's initial project is currently the largest proposed carbon capture project in the world. In partnership with the City of Farmington (a current and future five percent owner of the San Juan Generating Station), Enchant has obtained the right to acquire a 95 percent interest in the San Juan Generating Station and plans to retrofit the generating station with carbon capture technology by 2023 in connection with the Public Service Company of New Mexico's and the other current owners' exit of their ownership of the facility in 2022. Our project is considered to be one of the first projects that can get over the finish line utilizing the recently revised form of the 45Q tax credit.

The San Juan Generating Station is currently a two-unit 847 MW coal-fired power plant operating in northwest New Mexico. The plant has several characteristics that favorably address elements necessary for operational and economic success. These characteristics include the existing nitrogen oxide, sulfur dioxide, particulates, and mercury pollution controls. The San Juan Generating Station also has a mine-mouth coal supplier with the ability to supply coal at favorable prices, access to existing electric transmission lines, and proximity to the Cortez Pipeline, an existing carbon dioxide pipeline with available capacity. This Cortez Pipeline currently serves the Permian Basin with carbon dioxide that is used for enhanced oil recovery.

Adding carbon capture to the San Juan Generating Station will make the regional electric grid more stable and more reliable. This is because it will provide dispatchable power with carbon dioxide emissions intensity of approximately 250 pounds per MWh that is calculated to be lower than a typical, new combined-cycle gas plant. Overall, we will capture and remove more than 90 percent of the carbon dioxide in the waste stream, a percentage that will be guaranteed by our technology provider Mitsubishi Heavy Industries, America.

Enchant's project will save 1,500, direct and indirect, existing jobs in rural San Juan County, New Mexico. Approximately 450 of these jobs are high paying union jobs at the mine and the power plant of which approximately 40 percent are held by members of the Navajo Nation. The project will preserve at least \$53 million annually in state and local tax revenues. Enchant also has a memorandum of understanding with the City of Farmington and San Juan College to train future workers. Currently, San Juan College is seeking a federal grant

from the Department of Labor to assist with this training program, which will start with online classes in the fall 2020 semester.

During the construction phase of the carbon capture portion of the project, two million worker hours of on-site labor will be required for the \$1.3 billion capital project. Additionally, Enchant will perform more than \$100 million in deferred maintenance at the San Juan Generating Station, and construct an approximately 21-mile CO₂ pipeline to interconnect with the Cortez Pipeline.

There is an important federal government role in supporting projects like this one. For example, there are currently two DOE cooperative funding agreements that are of direct benefit to the San Juan Generating Station project. The first is the Front-End Engineering Design ("FEED") study for retrofitting it with carbon capture utilization and storage technology. The FEED study is underway and a collaboration between Enchant Energy LLC, a wholly owned subsidiary of Enchant, and the City of Farmington. The FEED study is funded through a DOE cooperative funding agreement in the amount of \$2.9 million.

Another DOE cost-share project is for comprehensive analysis of a geologic sequestration site in northwest New Mexico near the San Juan Generating Station to accelerate deployment of carbon capture utilization and storage technology at SJGS. A \$22 million DOE cooperative funding agreement was awarded to the New Mexico Institute of Mining and Technology (New Mexico Tech). The award includes \$17.5 million from DOE and \$4.5 million in cost sharing from the other parties, including Enchant, to the agreement. The data and analyses produced under the agreement will be used to prepare, submit and attain a permit from the U.S. Environmental Protection Agency (EPA) to potentially construct a Class VI well (carbon dioxide injection well), that would allow for geologic sequestration of potentially all of the lifetime metric tonnes of carbon dioxide at a site near San Juan Generating Station.

Conclusion

In summary, federal engagement with the nascent carbon capture industry is vital to its success, especially in these Coronavirus times. Given that private capital markets for debt and equity are essentially frozen because of COVID-19, capital raising is challenging. These capital-intensive projects, such as Enchant's San Juan Generating Station, require billions of dollars in project finance.

Federal programs such as the following will benefit from Congressional review to understand the best policy enhancements:

- 1) the IRS 45Q Carbon Capture Tax Credits (45Q);
- 2) the DOE Loan Guarantee Program (DOE LGP); and
- 3) the U.S. Department of Agriculture's (USDA) Rural Utilities Service Loan (RUS).

These federal programs will benefit from an extension of their current statutory filing deadlines, additional congressional appropriations, and a thorough review of their eligibility criteria. In particular, in the case of the RUS, its underwriting criteria related to rural offtake could have expanded eligibility definition of its "rural benefit". Moreover, the 45Q tax credit should be expanded from a 12-year operational life to a 20-year operational life. This will allow for investors to recoup their at-risk capital over a longer time frame, which is important given the challenges of developing such projects. The 20-year life would also enhance the ability of 45Q projects to compete with other sources in offering power purchase agreements to local utilities, which typically ask for 20-year terms.

Finally, and most importantly, the 45Q tax credit should be "refundable," just like the wind energy tax credit was during the Great Recession. It is well understood that during those recession years, the private sector "tax equity" markets were inaccessible due to dramatically reduced institutional income levels. It is generally acknowledged that the wind industry, in particular, was saved by the direct federal investment option (in lieu of the annual tax credit) created in 2009. In numerous briefing and white papers prepared by the American Wind Energy Association, this provision was the saving grace of the wind industry. A "refundable" or "direct pay" credit can do the same for carbon capture. Enchant would like to work with the Committee to develop this concept as it relates to the Section 45Q tax credit in more detail.

Congress should also extend the 45Q tax credit project date requirement. Currently, the 45Q tax credit requires projects to begin construction by December 31, 2023. With the time delay in the Internal Revenue Service providing the clarity to the market for 45Q is certainly makes sense that this begin construction date be moved further out in time.

In addition, it is important to mention the streamlining of environmental regulations. If projects like Enchant's are going to succeed, direct sequestration is necessary to have as an option as it avoids the oil-price link that is standard in enhanced oil recovery deals. The regrettable lack of streamlining is seen by the five years it took to permit the second-ever Class VI carbon dioxide injection well, that is directed at containing CO₂.

We believe that Congress should increase funding for the EPA in order that additional staff can more quickly review the environmental permits for Class VI Underground Injection Control (UIC) wells. This will also address certain development barriers such as liability uncertainties. Good public policy suggests that Class VI environmental reviews should be appropriate to the very modest impact that comes from sequestering carbon dioxide.

Thank you for this opportunity to share Enchant's views. I look forward to working with the Committee on these important matters.

Sincerely,
Cindy A. Crane

777 Overland Trail, Ste 208
P.O. Box 2528 Casper, WY 82602 O: 307-333-6979 F: 307-333-6980

Glenrock Energy, LLC

Oil & Gas Project Development & Management

425 Madison Avenue
19th Floor New York, NY, 10017 O: 212.453.6703
F: 212.753.3829

August 19, 2020

Statement of Terry Manning
CEO, Glenrock Petroleum

Before the Senate Committee on
Environment and Public Works

Mr. Chairman, Ranking Member Carper and Members of the Committee,

Thank you for holding this field hearing on Wyoming's leadership in the capture, utilization, and storage of carbon dioxide. The daily news, reporting this week's electrical outages in California, reminds us that we desperately need reliable, non-intermittent sources of power. If clean energy is to be achieved in a way that does not sacrifice the standard of living graced to the citizens of America, then coal-burning plants with carbon capture *must* play a prominent role.

The Environment and Public Works Committee has shown leadership on this issue. By passing out of committee the USE IT Act, the Committee has supported next generation carbon capture technology and advanced the development of CO₂ pipeline infrastructure. We thank Chairman Barrasso, Ranking Member Carper and the eight other members of the Committee who cosponsored the legislation.

About Glenrock Energy

Glenrock Energy was founded in 2016 with the intention of becoming a major carbon-negative energy producer. The company owns over 33,000 acres of mostly contiguous mineral leasehold, encompassing substantially all of the Big Muddy and South Glenrock oil fields.

In the course of its work, Glenrock has worked with Congress to pass the FUTURE ACT and submitted comments to the federal Department of

Energy and the Internal Revenue IRS on 45Q tax regulations. In the Wyoming State Legislature, Glenrock has promoted carbon capture as a win-win-win: good for the economy, good for the people of Wyoming, and good for the environment. In the wake of the Covid pandemic, Glenrock believes that more strongly than ever.

Wyoming Leadership on Carbon Capture

Wyoming has a geography and geology more conducive to enhanced oil recovery than anywhere else in the nation. The state has no right-of-way impediments to carbon-dioxide pipelines, for example. With its fleet of existing coal-burning power plants, Wyoming has many sources for low-cost anthropogenic carbon dioxide—and the state also has over 1.6 billion barrels of oil that can be recovered from conventional reservoirs with sufficient carbon dioxide. The combination is irresistible.

Meanwhile, Wyoming's state government and national representatives understand the benefits of carbon capture better than anyone else—beginning with you yourself, Chairman Barrasso. We all owe you a debt for your hard work on carbon capture. You cosponsored the FUTURE Act, obtained IRS regulatory guidance for 45Q, cosponsored the USE IT Act, and more. You are not alone. The Wyoming legislature's passage of SF 159, SF 021, SF 037, and HB 200 demonstrates its shares your commitment to advancing carbon capture.

With all these advantages, Wyoming can and should become the international model for carbon capture. The benefits start at the local level. This technology allows us to keep our existing coal plants, preserving the towns in which they are important economic entities. It maintains a local market for Wyoming coal, even while it shows the world how that coal can be used in environmentally friendly ways. Carbon capture increases Wyoming oil production, generating important tax revenues for the state. The low cost of the electricity it produces makes the state attractive to data centers and other power-hungry industries. Carbon capture even allows the state's expertise to be contracted by those outside Wyoming, helping local companies prosper.

The benefits flow to the rest of the nation, with carbon capture joining wind and solar to provide clean energy to the national grid—and a clean energy that helps wind and solar by being continuous. In addition, from there, the benefits extend to the world, with reduced emissions helping the environment recover.

Call for 45Q Extension and Parity

For these benefits to materialize, it is essential that 45Q be extended. The IRS took over two years to issue regulations on 45Q, precluding new projects from getting financed. Now, we are in the worst economic crisis since the Great Depression, and the market for tax equity, which enables the financing of these projects, has collapsed. Tax-equity markets rely on companies contracting to purchase tax credits to offset tax liabilities to the Federal government. The future stream of income from tax equity buyers enables clean energy projects to be financed today. Now, with many companies suffering staggering losses, and others uncertain of their income in a post-pandemic world, there is no market for tax equity, and carbon capture projects cannot be financed. An extended time period is needed to compensate for the IRS delays and pandemic's disruption.

It is also essential that 45Q receive parity with wind and solar tax credits. The House of Representatives has already passed legislation to make the Investment Tax Credit (ITC) and Production tax credit (PTC) refundable. If the ITC and PTC have this status but carbon capture does not, all the promise of carbon capture will be lost. The investments it needs will flee, not because of anything intrinsic to these technologies but solely because of the tax code. That is not the American way.

I thank the Committee for allowing me to submit this statement for the record.



**GREAT PLAINS
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Better Energy.
Better World.

Written Testimony of
Brad Crabtree Vice President,
Carbon Management Great
Plains Institute

Before the
Senate Environment and Public
Works Committee

August 19, 2020
Field Hearing to examine "Energy and
Environmental Innovation: Wyoming's
Leadership in Using and Storing Carbon
Dioxide Emissions"

Great Plains Institute
Testimony:

**Federal Support for Carbon Capture Technologies
to Critical to Scaling the Carbon Capture Industry**

Chairman Barrasso, Ranking Member Carper and Members of the
Committee,

Thank you for convening this field hearing on the leadership of the state of Wyoming in the development of a domestic carbon capture industry. Holding this field hearing at the Wyoming Integrated Test Center is fitting, as Wyoming is a leading state in the development of commercial-scale carbon capture, utilization, removal and storage technologies. In a country as economically diverse and varied in resource potential as the United States, there must be multiple pathways to net-zero carbon emissions by midcentury if we are to meet our climate goals, and Wyoming has distinguished itself in charting a path toward climate stewardship that appropriately draws on the comparative advantages of a rural energy-producing and natural resource-rich state.

Additionally, by introducing and passing out of this committee the USE IT Act, the Environment and Public Works Committee has also shown tremendous leadership and interest in developing the next-generation of carbon capture technologies, including direct air capture (DAC), carbon utilization, and planning the deployment of infrastructure that will be necessary to capture,

transport, and store carbon captured from industrial facilities, power plants and from ambient air. We recognize and thank Chairman Barrasso, Ranking Member Carper and the eight other members of the Committee from both political parties who have cosponsored the legislation.

About the Great Plains Institute

The [Great Plains Institute](#) (GPI) is a nonpartisan nonprofit with roots in the Upper Midwest and programmatic activities in carbon capture dating back to 2002. The goal of GPI's carbon management program is to accelerate economy wide commercial deployment of carbon capture, transport, use, removal and geologic storage to take full economic advantage of our nation's energy resources, protect and create high-wage jobs, and meet midcentury goals for reducing carbon emissions. Carbon capture can reduce emissions across multiple industries and is the only technology available to manage emissions from several industrial processes essential to modern economies. It can also be paired with bioenergy projects to produce energy with net zero or negative carbon dioxide (CO₂) emissions. GPI engages with a broad set of interests at the federal, regional and state levels to advance financial incentives and other policies that will drive investment in and deployment of carbon capture, CO₂ transport infrastructure and geologic storage projects.

Our work is national in scope, including focused work at the federal level and complementary state and regional initiatives spanning the Great Plains, Gulf Coast, Midwest and Mountain West regions. GPI coordinates the 16-state State Carbon Capture Work Group, originally co- convened by former Wyoming Governor Matt Mead and Montana Governor Steve Bullock, and the [Regional Carbon Capture Deployment Initiative](#) that brings together nearly 400 state officials and stakeholders across two dozen states. Additionally, the Great Plains Institute convenes the national [Carbon Capture Coalition](#), which is comprised of more than 80 companies, unions and NGO building federal policy support for economy-wide deployment of carbon capture, transport, use, removal and storage.

This testimony will address:

- 1) The ongoing federal role in the development and commercialization of carbon capture technologies;
- 2) Wyoming's leadership in developing carbon capture technology;
- 3) Carbon capture's role in meeting midcentury climate goals;
- 4) Carbon capture's job creation potential; and
- 5) Key areas the federal government must invest in to ensure commercial-scale deployment of carbon capture, including direct air capture, carbon utilization, and CO₂ transport infrastructure addressed in the three titles of the USE IT Act.

The Federal Role in Carbon Capture Deployment

The landmark bipartisan reform and expansion of the federal 45Q tax credit through passage of the FUTURE Act in 2018 has spurred tremendous interest from lawmakers, states, and stakeholders in commercializing carbon capture technologies. The Carbon Capture Coalition has spent over two years building consensus on the effective implementation of 45Q, including three comprehensive submissions of consensus model guidance and recommendations to Treasury and the IRS in [November 2018](#), [June 2019](#), and [July 2020](#). IRS finalizing the proposed rule for 45Q will provide long overdue regulatory and investment certainty to unlock billions of dollars in private capital for carbon capture projects to complete planning, engineering, permitting and financing to begin construction by the end of 2023 and qualify for the credit.

Looking ahead, and building on the success of wind, solar and other low- and zero-carbon technologies, carbon capture will need a full portfolio of federal policies and parity of support to achieve economywide deployment. This includes tax credits and other incentives, federal funding for research, development and demonstration (RD&D), and federal financing in order to leverage private investment in carbon capture, transport and storage projects that will spur continued innovation and improved performance, thus driving down costs and attracting still more investment that further accelerates deployment.

It is well established that there are long lead times for advancing capital-intensive energy technologies from concept to demonstration to commercialization, making it difficult to attract sufficient private investment to scale up these technologies in the marketplace, absent federal support.

The United States leads the world in the commercialization of carbon capture, and there is bipartisan support for capturing and utilizing CO₂ and its precursor carbon monoxide. Carbon oxides may be captured from diverse sources, including a broad range of industrial facilities, power plants and ambient air through DAC. Sustained federal investment in these technologies represents a genuine win-win for our nation's economy and environment, greatly reducing our nation's emissions, while benefitting energy-producing and industrial regions with the retention and creation of high-paying jobs and a sustainable tax base.

Reflecting growing momentum and political support, there have been numerous bipartisan Senate bills introduced in the 116th Congress that would further carbon capture deployment, whether through bolstering or creating new federal research and development programs or reducing the cost of attracting private capital to develop and build capture projects. They include the following:

- **The USE IT Act** (S. 383) supports RD&D for carbon utilization and DAC and facilitates collaboration on planning and permitting CO₂ transport infrastructure;
- **The Carbon Capture Modernization Act** (S. 407) enables existing power plants to access available Section 48A tax credits for greater deployment of carbon capture in the power sector;
- **The Carbon Capture Improvement Act** (S. 1763) allows carbon capture projects to access tax-exempt private activity bonds;
- **Financing Our Energy Future Act** (S. 1841) makes carbon capture and utilization projects eligible for tax-advantaged master limited partnerships;
- **The EFFECT Act** (S. 1201) reauthorizes, updates and expands RD&D programs for carbon capture, utilization, removal and storage;
- **The LEADING Act** (S. 1685) establishes a RD&D program for carbon capture at natural gas energy facilities; and
- **The Clean Industrial Technology Act** (S. 2300) stands up an industrial decarbonization RD&D program, which includes carbon capture to address industrial emissions.

Additionally, several of these bills have been packaged into the American Energy Innovation Act, which, if passed, would represent the most consequential legislation for carbon capture since enactment of the FUTURE Act. The expansion of federal carbon capture RD&D programs will help drive down the costs and improve the performance of next generation clean energy and industrial technologies, thus providing more options in both the U.S. and globally to meet midcentury emissions reduction goals.

Finally, similar or companion legislation in the House has been introduced and, in several cases, reported out of committee on a bipartisan basis. Recently, direct pay and a two-year extension of the 45Q tax credit passed the full House as part of H.R. 2, the Moving Forward Act. Notably, far-reaching bipartisan RD&D amendments for carbon capture, utilization, removal and storage were also included in and passed as part of H.R. 2, providing a potentially promising basis for Senate negotiations with the House to enact provisions of the USE IT Act into law.

Carbon Capture's Role in Addressing Climate Change

Analysis by the International Energy Agency (IEA) has determined that deployment of carbon capture technology is critical to achieve midcentury global temperature targets. Nearly every global temperature scenario put forth by international organizations and agreements requires dramatically accelerated use of carbon capture to meet its goals. Underscoring carbon capture's central role in mitigating climate change, the United Nations Intergovernmental Panel on Climate Change (IPCC) found that carbon mitigation under the 2⁰ Celsius scenario would cost 138 percent more if carbon capture were not included as an emissions reduction strategy.

Carbon capture has been successfully deployed at large scale in certain industrial sectors for decades and has entered commercial-scale operation in the power sector in recent years.

Industrial CO₂ emissions account for about 33 percent of US stationary emissions, according to the US Environmental Protection Agency. Many industrial facilities in ethanol, gas processing, ammonia and hydrogen production offer immediate opportunities for relatively low-cost carbon capture due to the high purity and concentration of CO₂ emissions coming off their production processes.

The IEA estimates that the global carbon capture industry will need to scale-up to over 2,000 facilities capturing 2.8 gigatons of CO₂ per year to limit warming to 2°C. To meet the more ambitious 1.5°C scenario, the IPCC estimates that 10 gigatons of CO₂ must be captured annually. To reach this level of ambition, the Global CCS Institute estimates that more than 2,500 large-scale carbon capture facilities will need to come online by 2040. It is estimated that half of these facilities will be in power, the other half in industrial sectors. Today, there are 21 large-scale carbon capture projects operating world-wide, with another 30 in various stages of development. Globally, 21 large-scale facilities currently capture approximately 42 million metric tons of CO₂ per year. The U.S. has 13 commercial-scale carbon capture facilities operating today, with the capacity to capture on the order of 25 million tons of CO₂ annually.

Reaching this scale of CO₂ capture and storage will require an accelerated, economywide buildout of capture projects across sectors, including heavy industry (e.g. cement, steel, chemicals and other vital industrial processes); ethanol, fertilizer and hydrogen production; refining and natural gas processing; power generation and DAC from ambient air. Additionally, a commercial-scale carbon capture industry will require the buildout of transport infrastructure to move CO₂ from where it is captured to appropriate geologic storage sites. Not only would this constitute a significant investment in domestic energy, industry and manufacturing, it would preserve and expand a high-wage jobs base in many regions of the country, while decarbonizing economic sectors that are fundamental to modern life, as we know it.

Wyoming is a Leader in Developing Carbon Capture Technology

Wyoming already ranks among the top states in the nation when it comes to carbon capture, transport and geologic storage, and it is even richer in potential. Wyoming is strategically positioned to become both a major source of CO₂ captured from industrial facilities and power plants, as well as a hub for the beneficial use and geologic storage of captured carbon. The state is one of the largest emerging hubs for CO₂ pipeline infrastructure and projects, serving not just Wyoming but linking to Colorado and Montana.

Ranked first among states in the production of coal and eighth in crude oil production, while also containing 23 facilities eligible for the reformed and expanded [45Q tax credit](#), Wyoming has immense opportunity for the deployment of carbon capture technology and geologic storage through enhanced oil recovery (EOR) and in saline formations to lower carbon emissions and transform captured carbon into an economic resource.

As one of the first states to enact legislation on carbon capture, utilization and storage, Wyoming now has among the most comprehensive legislative frameworks for incentives and regulation of carbon capture and geologic storage. Uniquely among states, Wyoming also developed a CO₂ Pipeline Corridor Initiative to facilitate the development of statewide and regional infrastructure for the transport and management of CO₂. With a supportive tax structure, comprehensive legislation, and geologic potential, Wyoming is projected to continue as a leader in carbon capture policy development and project deployment.

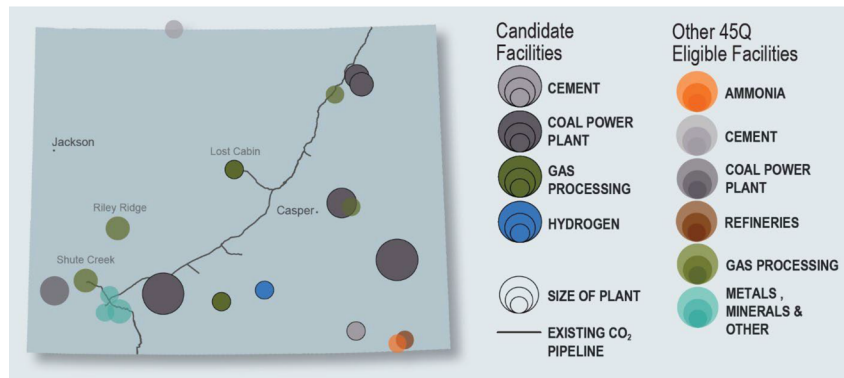


Figure 1: 45Q Eligible Facilities in Wyoming. Wyoming has many facilities large enough to qualify for the 45Q carbon capture tax credit, including coal power plants, gas processing facilities, and petroleum refineries. Facilities identified by the Regional Carbon Capture Deployment Initiative as potential early candidates for capture retrofit based on emissions, equipment, and estimated capture cost, are shown with outlines and darker colors. Source: Great Plains Institute 2019, EPA 2018.

Carbon Capture as a Jobs Creator

The current COVID-19 pandemic has wreaked havoc on much of the economy, and the power and industrial sectors are no different. The IEA estimates that "global energy demand will fall six percent in 2020 - the equivalent of losing the entire energy demand of India, the world's third largest energy consumer."

The IEA also estimates that global investment in energy technology is set to drop 20 percent in 2020, the largest ever one-year decrease, and thousands of jobs have been lost as energy projects have stalled. The current pandemic offers both the challenge and opportunity to rebuild and retool our energy sector better and cleaner than before. Carbon capture has a unique role to play in the broader economic recovery - both as a jobs creator and an emissions reduction tool. Fostering carbon capture deployment at levels needed to meet midcentury climate goals will result in dramatic growth in employment provided by the carbon capture industry, including both project jobs (primarily construction) and operational jobs featuring a mix of skill levels. If commercially deployed globally to address emissions as part of a broad suite of zero- and low- carbon technologies, the Global CCS Institute has found that the carbon capture industry would employ between 70,000 and 100,000 construction workers and 30,000 to 40,000 facility operators in 2050, with additional employees to build and maintain a CO₂ transport and storage network. Additionally, carbon capture retrofits will decarbonize existing facilities, preventing their retirement and loss of associated high-wage jobs.

Carbon capture retrofits of industrial facilities and power plants support high-wage jobs in particular; indeed, they provide among the most desirable green jobs, given that employment associated with heavy industry (refining, chemicals, cement, steel, etc.) and electric power generation pays more than the average for states in which such facilities are located. In addition, new and innovative high-skill and high-wage industries will play a role in commercializing the carbon capture industry, including jobs associated with new negative emissions and carbon utilization technologies.

		PROJECT JOBS	OPERATION JOBS	
CO ₂ TRANSPORT INFRASTRUCTURE	CARBON CAPTURE RETROFIT* INDUSTRY	STEEL MILL	1,680 – 3,030	170 – 310
		REFINERY	440 – 760	40 – 70
		CEMENT PLANT	430 – 690	60 – 110
		HYDROGEN PLANT	175 – 300	20 – 30
		ETHANOL PLANT	30 – 50	5 – 10
	POWER	COAL POWER PLANT	1,800 – 3,350	160 – 300
		NATURAL GAS COMBINED-CYCLE POWER PLANT	1,140 – 2,090	100 – 180
		TRUNK LINE (20" DIAMETER PIPELINE, 200 MILES LONG)	1,250 – 2,190	8 – 20
		FEEDER LINE (12" DIAMETER PIPELINE, 50 MILES LONG)	250 – 370	2 – 5
*By facility type				

Figure 2: Job Estimates by Facility Retrofit. Drawing on GPI's modeling of economically feasible capture projects (described later), the Rhodium Group has provided preliminary analysis of the jobs potential for a typical carbon capture facility across several industries. The range in jobs numbers reflect differences in project sizes in the GPI project database. Source: Rhodium Group, 2019.

The USE IT Act's Role in Building a Commercial-Scale Carbon Capture Industry

While the 45Q tax credit is foundational to spurring additional investment in carbon capture technology, passage of associated policies will provide important research and development dollars to drive down the costs associated with both existing and new technologies, as well as helping to develop new technologies crucial to meeting midcentury climate goals and to preserving and creating high-wage industrial, manufacturing and energy production jobs in carbon-intensive sectors of our economy.

Enactment of the Senate-passed USE IT Act would support research, development and demonstration of DAC technology and beneficial uses of carbon captured from industrial, power and DAC plants that reduce emissions, as well as foster cooperative planning and permitting of pipeline infrastructure to transport CO₂ from where it is captured to where it can be safely and permanently stored or put to beneficial use. Passage of the USE IT Act and associated carbon capture legislation now before the 116th Congress would allow energy producing states like Wyoming to play a pivotal role in reducing emissions and sustaining energy production and high-wage jobs.

The USE IT Act contains three titles and remaining testimony will cover the importance of scaling these three

technologies: direct air capture, carbon utilization and CO₂ transport infrastructure.

Direct Air Capture

While capturing emissions directly from industrial and power sources is critical to addressing climate change, negative emissions technologies (NETs), including DAC, will be required to manage atmospheric concentrations of CO₂. The IPCC estimates that, in addition to actively avoiding emissions, whether through renewables, energy efficiency or other zero-carbon technologies, there will be a need to remove anywhere between 100 to 1,000 gigatons of CO₂ by 2100, to limit warming to 1.5° C.

Deployed at the necessary scale, these NETs will remove approximately 10 gigatons of CO₂ annually by mid-century, and 20 gigatons of CO₂ by end of century, particularly to offset hard-to-decarbonize sectors, such as significant portions of industry and heavy-duty transportation. In addition to their necessary role in meeting the 1.5° C goal, in the likely scenario that we exceed our global carbon budget, any additional emissions “overshoot” would need to be offset by NETs. Deploying NET technologies at this scale will require massive federal and private investment, as well as international coordination. While DAC technology is commercially available at smaller scales and there are several projects in the development pipeline, new policies are needed to drive down the costs of deployment. According to research from the [Rhodium Group](#), DAC will need to manage between 689 to 2,260 million tons of carbon annually to meet a 1.5° C target.

Additionally, if DAC deployment reaches the full scale needed to attain midcentury climate goals, it will create tremendous domestic employment and business opportunities. In analyzing the jobs and economic development created by DAC deployment, the Rhodium Group found that building just one average-sized facility¹ would create approximately 3,500 project jobs, with an additional 278 jobs created by ongoing plant maintenance. The associated jobs span a range of sectors, including industrial manufacturing, construction, engineering, and steel and cement manufacturing. Business opportunities from scaling DAC exist in equipment manufacturing, cement, steel, chemicals, electricity and natural gas. With a commercial-scale DAC industry, employment in steel and chemical sectors could be boosted 50 percent by large-scale DAC deployment alone, and the construction, engineering, and equipment manufacturing sectors could see 300,000 new jobs.

Carbon Utilization

Carbon utilization is the production of valuable products from carbon oxides (carbon monoxide- CO and carbon dioxide- CO₂) captured from gaseous waste streams, or from the

atmosphere, that result in a reduction of greenhouse gas emissions as compared to an incumbent process or product. Carbon utilization may include the production of a wide variety of commodities or products sourced from waste gases or DAC and includes low and zero-carbon fuels, chemicals, plastics, advanced materials, industrial gases and fluids, building products as well as agricultural and food feedstocks.

Carbon utilization represents yet another area of public and private sector leadership in Wyoming, with the Integrated Test Center location for this hearing being a prominent example. The Integrated Test Center is pursuing carbon utilization innovation, to add economic and environmental value to captured carbon.

Increasingly, carbon utilization is seen as an important complement to large-scale carbon storage as it provides value-added markets for carbon capture operations and is an important component of a circular carbon economy. Taken together, the [National Academies of Science](#) has estimated that utilization pathways could take up to 1 gigaton of CO₂ per year. The growing carbon-to-value market could be worth an estimated \$800 billion a year by 2030, with most value seen in high-volume products, including aggregates and fuels.

One prominent example of the opportunity inherent in carbon utilization is the US technology firm LanzaTech. Through a partnership with the world's largest steel producer, ArcelorMittal, the company is are constructing a commercial-scale facility in Belgium to use microbes to transform waste carbon monoxide emissions captured from steel production into 17.5 million gallons of ethanol annually. This ethanol can be converted to jet fuel or a wide range of chemicals and other products. The technology pathway LanzaTech is pursuing is just one example of carbon utilization where waste gases that would otherwise be combusted and released to the atmosphere as CO₂ are instead converted into valuable products.

MARKET SIZE: \$ BILLION	2020	2025	2030	GHG MITIGATION: BILLIONS OF METRIC TONS OF CO ₂	2020	2025	2030
Concrete	60	200	400	Concrete	*	0.7	1.4
Fuels	5	60	250	Fuels	*	*	2.1
Aggregates	4	30	150	Aggregates	*	0.7	3.6
Algae Ag/Feed Products	3	10	120	Algae Ag/Feed Products	*	*	1.2
Algae Fuels/Chemicals	2	4	200	Algae Fuels/Chemicals	*	*	2
Polymers	1	3	25	Polymers	*	*	*
Commodity Chemicals	0	5	12	Commodity Chemicals	*	*	*

* less than 0.5 billion tons CO₂

Figure 3: Market Size and GHG Mitigation Potential of Carbon Utilization Sectors. Source: *Carbon Utilization— A Vital and Effective Pathway for Decarbonization*, Center for Climate and Energy Solutions (C2ES), 2019.

A recent report from [C2ES](#) finds that high-volume products sourced from carbon utilization, including concrete and aggregates, as well as fuels, could drive both volumes of carbon utilization and market value. However, realizing this market will require build-out of CO₂ transport infrastructure, as well as breakthroughs in carbon utilization pathways enabled by federal RD&D. Finally, they will need to be tested and commercialized at places like Wyoming's Integrated Test Center.

CO₂ Transport Infrastructure

With the availability of a foundational federal incentive such as 45Q to help finance carbon capture deployment, interest and attention from policymakers and stakeholders is expanding to include CO₂ transport infrastructure. CO₂ transport infrastructure will play a critical role in enabling economywide deployment of large-scale carbon management. Here again, Wyoming stands out, with its national leadership on carbon capture reflected in the state's long-term, proactive approach to planning and preparing for the responsible buildout of CO₂ transport networks to meet both economic and emissions reduction goals. No other state has devoted so much attention to the infrastructure side of carbon management.

In 2012, the state launched the Wyoming Pipeline Corridor Initiative (WPCI) to identify approximately 2,000 miles of optimal pipeline corridors in 25 segments to provide CO₂ transport infrastructure within the state. These pipeline corridors will ultimately link industrial facilities and power plants with saline formations and oil fields best suited for permanent geologic storage. Coordinated state planning will also minimizing costs, uncertainty, and environmental impacts of infrastructure as well as the time, uncertainty and cost associated with permitting projects.

Initiated by former Governor Mead and further supported by Governor Gordon, Chairman Barrasso encouraged the

¹ Assumes that a typical DAC plant captures one million tons of CO₂ per annum.

Administration to prioritize CO₂ transport infrastructure and review of Wyoming's statewide effort, and the WPCI recently received a favorable decision on its environmental impact statement from the Bureau of Land Management. We also want to recognize our colleague Matt Fry, formerly on Governor Mead's staff and now with the Wyoming Game and Fish Department, whose dedication and perseverance over nearly a decade helped make the success of the WPCI a reality.

The WPCI has already served as a model for the work of other such initiatives. The State Carbon Capture Work Group, inspired by Wyoming's efforts, released a [white paper](#) in early 2017 on the development of national CO₂ transport networks that included recommendations for federal financing of such infrastructure. These recommendations informed the development of the INVEST CO₂ Act (H.R. 4905), introduced last year by Representative Bustos (D-IL). The Initiative also provided a basis for the provisions in Title III of the USE IT Act to facilitate collaborative CO₂ transport infrastructure planning among federal agencies, states, tribal governments, and industry, NGO and other key stakeholders.

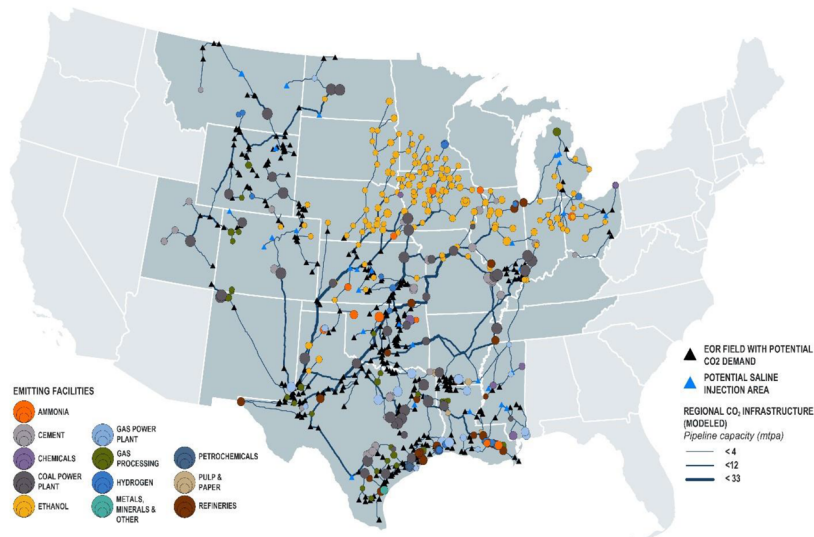


Figure 4: Near and Medium-Term Capture, Transport and Storage Deployment. Source: *Transport Infrastructure for Carbon Capture and Storage: Regional Infrastructure for Midcentury Decarbonization*, Great Plains Institute, 2020.

Often overlooked is the critical role that that the buildout out of CO₂ transport infrastructure must play if carbon capture is to fulfill its necessary contribution to meeting midcentury climate goals. A national modeling team coordinated by GPI, and featuring participation by the University of Wyoming's Enhanced Oil Recovery Institute, recently completed a two-year long [modeling and analysis](#) of regional-scale deployment of carbon capture, transport and geologic storage. This work underscores both the potential for, and essential importance of CO₂ transport infrastructure deployment, to enable large-scale carbon management.

45Q tax credit-eligible industrial and power plant sources of CO₂ and suitable geologic storage reservoirs across a 24-state study region, together with the results of a facility-by-facility analysis of carbon capture costs, were fed into Los Alamos National Laboratory's SimCCS model to identify optimized CO₂ transport networks capable of achieving economy-of-scale cost savings, while minimizing environmental and other impacts.

Modeling results show that near and medium-term deployment based on the 45Q tax credit, market demand for CO₂, coordinated infrastructure planning, and low cost financing results in the capture, transport and storage of 281 million metric tons per of CO₂ annually, or nearly one-third of a gigaton of CO₂ (See Figure 4). Midcentury deployment of even more robust CO₂ transport networks based upon further policy support and greater cost reductions result in annual capture, transport and storage of 669 million metric tons of CO₂ annually, or two-thirds of a gigaton (See Figure 5).

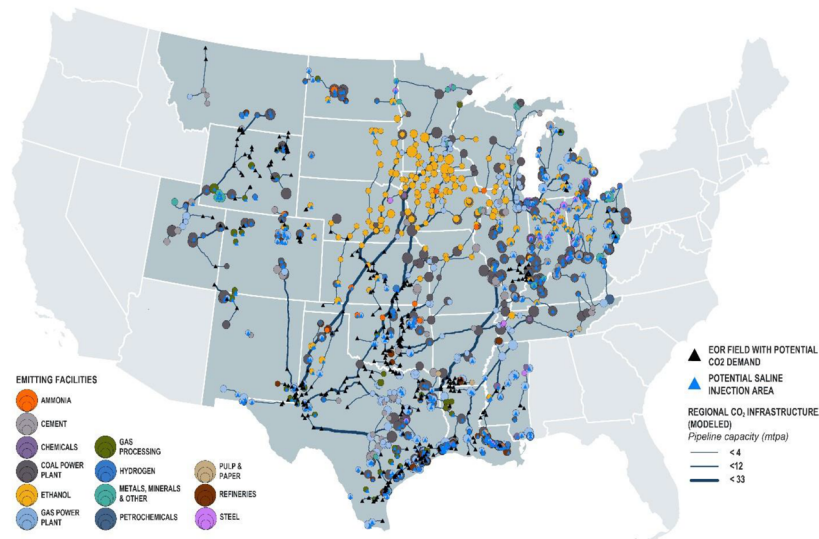


Figure 5: Midcentury Capture, Transport and Storage Deployment. Source: *Transport Infrastructure for Carbon Capture and Storage: Regional Infrastructure for Midcentury Decarbonization*, Great Plains Institute, 2020.

To put these results in perspective, U.S. annual CO₂ emissions are on the order of five gigatons. IEA's modeling of the 2^o C target suggests that we must be achieving 20 percent of our annual emissions reductions by 2050 from carbon capture and storage. Given that the midcentury scenario modeled by GPI

and colleagues shows roughly two-thirds of a gigaton of capture, transport and storage potential across 24 states, it is expected that expanding the current analysis to the rest of the country will reveal the **potential for at least a gigaton of annual carbon management nationwide by midcentury**. This level of carbon capture is in line with the IEA's modeling of the technology's expected contribution to achieving to the 2⁰ C target by 2050.

Beyond the climate necessity, the economic benefits of regional CO₂ transport infrastructure deployment networks will be profound. Figure 6 below highlights the projected capital investment, project wages and annual operations and maintenance expenditures associated with both the near and medium-term and midcentury deployment scenarios. It should be noted that these projections do not include the enormous and beneficial economic and jobs implications of futureproofing existing domestic energy, industrial production and manufacturing for a low-carbon economy by deploying technology and infrastructure for decarbonization.

Scenario	CO ₂ Stored	Miles of Transport Network	Capital Investment	Project Labor Investment	Annual O&M Spending
Near- and Medium-Term	281 million metric tons	29,710 miles	\$16.6 billion	\$14.3 billion	\$252 million
Midcentury	669 million metric tons	29,922 miles	\$19.3 billion	\$15.3 billion	\$254 million
Impact of Midcentury planning horizon	x 2.38 more CO ₂ stored	+0.7%	+16.3%	+7.0%	+0.8%

Figure 6: Economic and Employment Implications of Near/Medium-Term and Midcentury Deployment Scenarios. Source: *Transport Infrastructure for Carbon Capture and Storage: Regional Infrastructure for Midcentury Decarbonization*, Great Plains Institute, 2020.

To realize climate, economic and jobs benefits on this scale by midcentury, federal policy leadership on CO₂ transport infrastructure planning and deployment is urgently needed to complement 45Q and other federal policies on the capture and storage side of the equation. Passage of the USE IT Act's Title III is an important first step to enable federal agencies, states and stakeholders to begin working together on a regional multistate basis, building on the example of what is already occurring in Wyoming. In addition, federal support for financing CO₂ transport infrastructure capacity along the lines of the current INVEST CO₂ Act, especially large-volume, long-distance common carrier trunk lines, must be part of a federal infrastructure package in the next Congress.

Conclusion

In summary, economywide deployment of carbon capture, use and geologic storage is not optional if we are to decarbonize industry and achieve midcentury climate goals. Carbon capture technology provides a viable pathway to enable the decarbonization and continued operation of existing and new industrial facilities, while avoiding plant closures and the offshoring of jobs and livelihoods. The US is the world's leader in the capture, use and geologic storage of carbon emissions from industry, with nearly 50 years of successful commercial and operational experience on which to build. In addition, we now have the opportunity to build new industries and associated high-wage jobs with both DAC and carbon utilization technologies.

Building on the deeply bipartisan success of the 2018 FUTURE Act, Congress must enact a broad portfolio of federal incentives and other policies to commercialize carbon capture, transport, use, removal and geologic storage and further incentivize DAC and carbon utilization. We must implement lessons learned from our successful experiences with wind, solar and other low and zero-carbon technologies to implement a broader policy framework for carbon capture. Carbon capture technologies have a pivotal role in sustain US leadership in energy technology and helping to put our nation on a path toward midcentury decarbonization.

Thank you again for your leadership and for the opportunity to provide testimony for the record. Sincerely,



Brad Crabtree
Vice President
Carbon Management
Great Plains Institute