CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

Road Map to At-scale Deployment of Carbon Capture, Use, and Storage

—Transcript of a webinar offered by the Clean Energy Solutions Center on 21 January 2020—
For more information, see the clean energy policy trainings offered by the Solutions Center.

Webinar Panelists

Jarad Daniels	U.S. Department of Energy
Guy Powell	Exxon Mobil Corporation
Nigel Jenvey	Cline & Associates

This Transcript — Because this transcript was created using transcription software, the content it contains might not precisely represent the audio content of the webinar. If you have questions about the content of the transcript, please contact us or refer to the actual webinar recording.

Kevin — Hello, everyone. My name is Kevin McCabe, and welcome to today's webinar, which is hosted by the National Renewable Energy Laboratory. Today's webinar is brought to you by representatives from the United States and the National Petroleum Council and is titled, "A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage." Before we begin, I'll quickly go over some of the webinar features. For audio, you have two options. You may either listen through your computer or over your telephone. If you choose to listen through your computer, please select the Mic and Speakers option in the audio pane. This method is preferred to ensure the best connection to the webinar platform. If you choose to dial in by phone, please select the Telephone option, and a box on the right side will display the telephone number and audio PIN you should use to dial in. If anyone is having technical difficulties with the webinar, you may contact the GoToWebinar's helpdesk for assistance by dialing the number shown on the slide. That is 888-259-3826.

If you would like to ask a question, we ask that you use the Questions pane, where you may type it in at any time during the webinar. Also, the recording of today's presentation will be added to YouTube at the link provided on this slide. Before we go over the agenda, I would like to share a few ways for our listeners to follow and engage with the CCUS initiative. You can follow the link or search for us on LinkedIn, as well as Twitter @ccuscem. For any and all questions, comments, or requests, you may also contact the initiative coordinator at the e-mail address shown here, cemccus@outlook.com.

Today's webinar agenda is centered around a presentation that will review developments by the National Petroleum Council, which recently released an

18-month study and final report on the actions needed to deploy CCUS technologies at scale in the United States. Before we launch into the presentations, I will provide a quick introduction of today's panelists. Then, following the panelists' presentations, we will have a Q&A session where the panelists will address questions submitted by the audience.

Our first speaker today will be Jarad Daniels, who leads the Office of Strategic Planning, Analysis, and Engagement within the United States Department of Energy Office of Fossil Energy, including domestic programs and international engagements conducted in close collaboration with industry, academia, and multilateral organizations. Mr. Daniels has 25 years of experience with the DOE managing advanced technology programs and working in several national laboratories throughout the United Sates. His expertise includes domestic and global energy and environmental technologies, policies, and programs. Mr. Daniels holds a Master of Science degree in chemical engineering from the University of California at Berkeley.

Following Jarad will be Guy Powell, Carbon Capture and Storage Venture Executive with the ExxonMobil Corporation. Guy received his Bachelor of Science degree in electrical engineering from Mississippi State University in 1990, and joined Exxon Company USA as a project engineer at the Baton Rouge Refinery in Louisiana. Guy has subsequently worked in a variety of technical, refinery operations, planning and business development roles of increasing responsibility for the corporation's downstream businesses in the U.S.A. and Europe. In 2014, Guy joined ExxonMobil's Corporate Strategic Planning Organization in Irving, Texas, as the corporation's greenhouse gas manager. In 2018, he assumed his current position as ExxonMobil's Carbon Capture and Storage Venture Executive, responsible for oversight of strategy, policy, advocacy, technology, and business development for ExxonMobil's global CCS activities. Guy is married, has two daughters, and his now based in Houston, Texas.

Finally, we will hear from Nigel Jenvey, Global Head of Carbon Management for Gaffney, Cline and Associates. Nigel has over 23 years of global oil and gas industry experience in technology, exploration, development, and production operations with major oil and gas operating companies. He is an industry leader in carbon management, an expert in carbon capture, use, and storage, having previously held roles such as the chair of the CO2 Capture Project, chair of the North American CCS Association, and program chair of the Society of Petroleum Engineers CCUS Technical Section. At Gaffney, Cline and Associates, Nigel leads the new global Carbon Management practice to help customers understand the wide variety of options available that will ensure continued business success through the energy transition. Nigel graduated from Imperial College, London with a master's degree in petroleum engineering, and from the University of Leeds, UK, with a bachelor's degree with honors in mining engineering. Nigel now lives in Houston, Texas, with his wife and two children. With those brief introductions, I would like to welcome Jarad to the webinar. Jarad?

Jarad Thank you very much, Kevin, and thank you all for joining us for the webinar today. I'll say a few words of introduction and then hand the presentation over to Guy and Nigel for the bulk of the material in today's webinar content. The National Petroleum Council is a federal advisory committee set up to advise, inform, and make recommendations to the Secretary of Energy of the United States with respect to any matter related to oil and gas.

On the next slide, you can see that about a year and a half ago, almost two years ago now, in September 2017, the Secretary of Energy requested the National Petroleum Council to conduct a study. He asked them to define the potential pathways for integrating CCUS at scale into the energy and industrial marketplace here in the United States and, more broadly, globally. The secretary asked the council to consider the technology options and technology readiness levels, market dynamics and economic and financing issues specific to and impacting carbon capture, utilization, and storage. He asked them to consider cross-industry integration and infrastructure issues, policy, legal, and regulatory issues, environmental footprint considerations for carbon capture, utilization, and storage, and, finally, to also consider and opine on public acceptance issues.

On the next slide, this basically boiled down to five key questions that the Secretary of Energy asked the National Petroleum Council to consider. The first question was, "What are U.S. and global future energy demand outlooks, and the environmental benefits that could come from the application of CCUS technologies?" The second key question was on R&D and technology and asked, "What R&D technology infrastructure and economic barriers must be overcome to allow CCUS to deploy at scale?" The third question was, "How should success be defined? In other words, how would you define at-scale deployment of CCUS?" This is a very simple but certainly not an easy question, and much time and effort was spent by the council through a year and a half worth of study analysis and effort to really get at the heart of this, which was, "How large can we deploy CCUS? How quickly can we deploy CCUS?" and, to determine success, when will we say, "This is deployment at scale in the United States context?" The fourth question was, "What actions can be taken to establish a framework that guides the public policy and stimulates the private sector investment to advance this deployment?" Finally, the fifth question was, "What regulatory, legal, and liability issues should be addressed to progress CCUS investment and enable the United States to be a global technology leader, and really drive the CCUS deployment at scale?"

Those were the five questions that the secretary asked. Again, very simple but not at all easy. What followed was a Herculean effort spanning about a year and a half of thoughtful analysis and discussion and debate to determine and deliver back to the Secretary of Energy the best answers to these questions. With that as a quick introduction of what the ask was of the group, I will now turn the webinar over to Guy and Nigel to lead us through the discussion of what transpired and the resulting answers to these key questions. Guy?

Guy Good morning, everybody. This is Guy Powell, and Jarad, I appreciate that introduction. As we go through and describe how we took on addressing the

secretary's questions, Nigel and I are going to tag-team this a bit and we'll go back and forth talking about various areas that we undertook. Before we get into that, I would just make one point. This, I believe, is the second or third time that this study has been presented post the actual presentation _____ National Petroleum Council _____ Secretary of Energy, which occurred on December 12th, so we would really appreciate, both in the questions and other feedback, if you guys could tell us is there a better way to explain and describe the study if something is not coming across, because we are very, very interested in getting this study out there to as many folks as are willing to hear it, because we do believe it was a very good piece of work, and will be instrumental in setting policy within the U.S. for the coming decades.

Jarad described the questions that the secretary asked. Before we talk about that, I wanted to talk very briefly on the makeup, the participants in the study, because that was something we spent a fair amount of time on when we were starting to get organized around what group of people should we involve in the study? There was a view early on that this doesn't just need to be an oil and gas industry study, as might be indicated by the NPC's name. In selecting the group of people that we did, we ended up with about 300 different participants representing more than 110 different organizations, almost 20 were from an international background, and drew participating from multiple industry sectors, only a third of which was oil and gas. From a government standpoint, we had participation from both the federal government, as obviously indicated by Jarad's presence, but as well as state governments, as well. We had a number of academia that we involved, both from notable universities, such as Stanford, University of Texas, University of Illinois, LSU, and several more.

We also invited the participation of several NGOs, the most notable of which are probably Environmental Defense Fund, Resources the Future, C2ES, and more. Then, from a financial community standpoint, we involved the major banks, including Bank of America, JPMorgan, but as well as several other investment and/or insurance firms to get their perspective. One of the reasons that we tried to draw the participation that we did is we wanted to produce a study that brought in multiple different perspectives and, over time, would stand the test of time from various different points of view, both from a political standpoint, as well as how people view climate change, so we thought it was extraordinarily important to bring in this wide array of participation. That is who was involved in putting this study together.

If you go to the next slide, we've got just a very simplistic view of how we actually structured the study, and there was a lot of discussion that went into this because, if you look at what the secretary asked, that covered, as Jarad said, relatively simple questions but not that simple to answer. Ultimately, what we ended up with is a three-volume study. The first volume includes the transmittal letter to the secretary, a copy of the secretary's letter, who was involved with the study, and then an executive summary, which also includes a roadmap to policy and how that policy could activate different layers of CCS capacity. Let me come back to Volume II, because that's where we're going to spend most of the time today, and I'll skip to Volume III, where we

assimilated a lot of information around CCS technology in the five areas that are listed here: capture, transport, storage, enhance or recovery, and use.

A lot of work went into that, a very good piece of work in terms of pulling together a lot of information that was already out there. Some new information, but I would say mostly what was done there is to take a look at the state of the technology. But, probably more importantly within those technology areas, what those sections did is assess the technologies and then assess what needs to be done from a research, development, and deployment perspective to increase the usability and reduce the cost of each one of those technologies. Those recommendations ultimately fed into Volume II, which is what I would describe as, if you will, the heart of the study. If you look at Volume II, it included Chapter One, which is the role of CCS in the future energy mix. This is a relatively short chapter, it's only about 20, 25 pages long, which describes how the study participants saw CCUS playing a role in the future energy transition, and specifically looked at the resources and capabilities that the U.S. has to develop CCUS technology in a big way. Chapter Two, Three, and Four are what I would call the true heart of the study.

Chapter Two describes how we assessed the supply chains and economics of CCUS being deployed in the U.S. Ultimately, what we did is produced a cost curve that described the cost of CCUS deployment for the top 80 per cent of stationary emissions in the U.S., and Nigel will get into detail on the methodology that we used to do that. Chapter Three then looked at the cost curve and looked at various policy recommendations that would be needed to activate, if you will, the less expensive tiers of CCUS deployment in the U.S. Ultimately, deploying with these _____ recommendations, about 500 million metric-tons-a-year capacity in the next 25 years, which is the level that the study ultimately defined to be at-scale deployment of CCUS, which was one of the fundamental questions that the secretary asked. To put that in context, 500 million metric tons of capacity would represent the application to CCUS of about 20 per cent of stationary emissions in the U.S. and about 10 per cent of total emissions. I think by all accounts, most people would look at it and say, "Yeah, that is a substantial deployment, and would define at-scale deployment."

Then, Chapter Four is a relatively short chapter, it's only about 20 to 25 pages long, but it does a very nice job at describing what needs to be done from a stakeholder engagement to incentivize further deployment of CCS, not only at a project level, but from a general stakeholder and population level, as well as what policymakers would recommend to do. This is how we structured the study. If you look at it right here, it looks very simplistic, but we went through literally months of deliberations to figure out how to best structure the study so that it had the greatest impact. With that, Nigel, I'll turn it over to you. Any comments _____ about this section, feel free.

Nigel

Many thanks, Guy. This is Nigel Jenvey. Good morning to everybody that's on the webinar. Go to the next slide. As Guy said, one of the key elements of the study was to evaluate the current state of cost and economics to really

derive the level of incentive and policy that's really required in order to get CCUS deployment at scale. We performed an ambitious _____ bottoms-up analysis of carbon capture, use, and storage costs across the largest sources of carbon emissions that comprise 80 per cent in total of all U.S. stationary sources. We knew that this was going to be a big task, but we have input from various companies and organizations that Guy took us through earlier on, and we've successfully delivered it. What it does and provides us, really, is the value of the incentives and the business case needed to enable deployment.

The case for RD&D and technology, and how this could lead to a reduction of costs in the future, we'll have a slide on that coming up, input into the economic impact assessment with respect to what value does CCUS really provide to society at large, and specifically to the country in terms of jobs created and GDP, gross domestic product. By having an economic model, as well, it also allowed us to assess the impact of various types of incentives to see what level of support actually each one could credibly achieve. That included both tax credits, of course, production tax credits like the 45Q, and improvements thereon, and also investment tax credits, lower cost of capital through private activity bonds or loan guarantees, and other financing structures that are available here in the United States to corporations, including master limited partnerships.

As you can see from the slide, this is to really orientate you on the next few slides, we've got a scale here, X and a Y axis, and the Y axis really is there to represent the cost to capture, transport, use and/or store one ton of CO2. Now, that's plotted against the X axis, which is the stationary point source volumes emitted in the U.S. total. You can see there on that scale, it goes up to 2.6 gigatons per annum, or about half the total current emissions. Of course, as Guy mentioned, we ultimately defined CCUS at scale to be 500 million tons per annum of CCUS deployment. Each one of these calculations, the assessment we did were sourced industry and location-specific. The cost and performance were based on Nth of a kind technology implementation, but technology that's currently available and deployed at large scale. Transparent assumptions, of course, is key, leveraging existing studies and industry experience, and we basically used a common set of financial assumptions: asset life of 20 years; an internal rate of return at 12 per cent; 100 per cent equity financing; an inflation rate at 2.5 per cent; and a federal tax rate at 21 per cent. We did that to ensure, indeed, open-book transparency of the way that we've structured and analyzed our costs. Okay, next slide.

Now we can see the cost curve that's been populated. Those axes now have been populated, and what you can see is two things. Of course, the gray shaded area, that's the marginal cost curve covering the largest 80 per cent of stationary source emissions as of today. That is a snapshot in time. This represents our view of costs today, as I said, with currently existing technology deployed in the Nth of a kind type fashion. But, also, what this chart shows is there are three illustrative examples of stationary sources that we really want to kind of ground you and use to highlight how we've built up the rest of the cost curve. One is for ethanol fermentation emissions, one is for cement, and one is for natural gas power generation. The light red color

you see in the bars indicates the cost of capture. The darker red color indicates the cost for both transport and storage/EOR use, enhanced oil recovery. Note that the width of the bar in these examples are illustrative. It doesn't really indicate the volume for each source, but of course it does within the gray shaded bar area on the slide.

Now, to get alignment on costs, of course we reviewed publicly available reports and supplemented those with industry expertise and experience, particularly for things like _____ costs in order to derive total as-billed costs. We then applied an open-book approach, as I mentioned earlier, to a set of uniform financial assumptions needed to produce a 20-year cash flow, and a fixed level of incentive over that period that would accommodate those financial assumptions. One thing to remember is that while each point source was modeled using methodology I previously described, the actual cost of a specific project may be different, as each project has unique attributes that could cause it to be higher or lower than the cost displayed on the model. But, on average, we believe we've done a thorough assessment in a consistent manner across all of these sources. Therefore, in order to ensure transparency going forward, this cost assessment tool will be provided online that would allow all users and you to change the costs, and also the financial assumptions in order to derive your own view of what the costs should be. We're aiming for that tool to be available at the end of January. Okay, next slide.

The last slide I'll talk about is indeed the role of research and development and technology. As stated earlier, our cost assessments were based on the Nth of a kind _____ using currently available and deployed technology at scale. That effectively means _____ absorption for capture, pipelines for transport, enhanced oil recovery for use, and saline formations for storage. Therefore, the role of R&D success has not been included in the determination of the gray-shaded area. This slide shows some yellow-orange downward arrows. That really is there to represent the notional cost improvements that could result from R&D investment. These improvements start at around 10 per cent and increase to 30 per cent at deployment, and R&D would mature over time. The gray-shaded curve is a snapshot, actually, in time. A logical approach, of course, would be to start deployment with the lowest cost sources on the left, and progress across to the right. As you can infer, successful R&D has the potential to reduce a significant amount of costs, and Guy will cover some of our specific recommendations later, but we believe that this could achieve a tenfold return over time in the amount of R&D investment. Okay, that's taking you through the cost assessment, and I'll hand back over to Guy who will take us through some of the phasing and the recommendations for each.

Guy

Sorry, guys. I was on mute. If you look at the curve that Nigel had presented, on the left-hand side, you see the dashed line, which shows the current capacity here in the U.S., which is about 25 million metric tons a year. What I'm going to take you through now is three phases of policy implementation, the specific recommendations for each one of those phases, and describe how much additional capacity we think can be brought on by implementing those particular policies.

The first phase we termed the Activation Phase. Essentially, we believe an additional 25 to 40 million metric tons of CCS capacity could come into existence within the next five to seven years, effectively doubling, or a little bit more, the capacity that exists in the U.S. today. Specifically, the recommendations that we presented is that we believe the IRS and Treasury should clarify certain aspects of the 45Q tax regulations. Things that we specifically called out were being very clear on what is required to demonstrate secured geologic storage and potentially introducing additional methods to do so, determining what constitutes start of construction, and several other things like that. There were about eight or ten different recommendations on how 45Q could be clarified, if you will.

The second thing is that we believe that the agency should establish a process to enable access to pore space that's controlled by the U.S. government. Today, there is not such a process, and that, in many circumstances, can become problematic. Then, the last thing that we recommended is that the EPA should shorten the period for Class VI permitting and move more to a risk-based approach for certifying and permitting Class VI wells. What I will point out here is in the activation stages, these are things that existing agencies can do within almost predefined regulations, and it doesn't necessarily require any congressional action. The thinking here was, "Let's go after the easiest things first, and things that we can do very quickly." As I mentioned, if these things are done, we assessed that an additional 25 to 40 million metric tons could be enabled in the next five to seven years.

If you go to the next phase, which we termed the Expansion Phase, you'll notice that the list of recommendations is much longer here. You'll also notice that within this set of recommendations, we have some suggestions for Congress, and I won't go through all of these but this is a phase where we believe the existing 45Q tax credit could be extended and expanded. There could be access given to other type incentives, like 48A and 48B tax credits, which are investment tax credits, could expand and extend the use of things like MLPs, private activity bonds, and other government funding mechanisms, increase support for well permitting, and include the ability to store CO2 in federal waters from all CO2 sources, which is currently not allowed. Then, you'll see a list of things that we also recommend that the agencies would do, from pore space access to addressing issues around long-term liabilities. It's a fairly exhaustive list. If all of these things were done, we believe that an additional 75 to 85 million metric tons of capacity could be incentivized, bringing the total at that point up to around 125 to 140 million metric tons. The other thing that I'll point out here is you'll notice that there's a fair amount of congressional action and a fair amount of agency action. What we're trying to do in this phase of the implementation is to effectively develop a durable legal and regulatory framework that would give investors confidence that we have all the things in place, beyond just incentives, to make CCS doable in a big way in the U.S.

If you'll then go to the At-Scale Phase, which is the final phase, you'll notice here we only have one recommendation, is that we believe under this _____ that Congress should put policies in place that would _____ amount to an

incentive between $90.00 and $110.00 a ton. At this level, we believe an additional 350 to 400 million metric tons could be incentivized, and this would bring the ultimate deployment in the U.S. to about 500 million metric tons, as _____ said, which we defined to be at-scale deployment. I'm going to turn it over here, but the point I'll make about this particular chart and this particular approach is, to my knowledge, this approach had not been taken in any CCUS study prior to this, where we looked at the cost, we looked at specific policy actions, and we described how those policy actions could in fact incentivize deployment of future CCS capacity, and how much that capacity could be. As I thought about this study, it struck me as this is probably the differentiating factor or feature of this study versus some of the others that might have been done in the past. Nigel, I'll turn it over to you on the next page.

Nigel

Thanks, Guy. The last couple of slides, public and industry engagement, last but certainly not least, within the study _____ of course the public and industry engagement recommendations, and the work that we did therein. Let me be clear that, of course, none of what we've taken you through today really can be accomplished without public understanding, public confidence, and also public support. That's why this event with the Clean Energy Ministerial today, and similar ones that we plan to undertake over the next few months, are critical, and we need your help. As CCUS ambassadors, we need to pick up the document, understand its application, and really to go consider taking implements in it, of course within the United States, for those that are aligned, but also think about taking this type of approach and looking at deploying it elsewhere around the world, as well.

The report recommends that the oil and gas industry play, of course, an integral role in the future of _____ given its relevant expertise, its capability, and of course resources. Collaboration, though, between organization sectors, not just the oil and gas industry, and countries is vital, highlighting the role that, of course, the Clean Energy Ministerial CCUS initiative plays in this regard, and also the commitments of others. One example, of course, we had last week was Microsoft and their announcement of $1 billion over four years to back companies and organizations working on technologies to remove or reduce carbon from the Earth's atmosphere. A great example of how industry and different sectors within industry are actually engaging with this, and of course there is a lot of commitment with the oil and gas industry putting into carbon capture, use, and storage technology and projects right now, which is great to see.

Okay, and the last slide, then, really just leaves you with our key messages. We think this report tells a great story, underpinned by technical and economic analysis – we've taken you through some of that today – and the experience and expertise of over 300 people that contributed to it from a diverse set of organizations. We think it is different to what has been produced before, as Guy mentioned. We hope that it will make a difference, not just in the U.S., but globally. Not many people realize the potential that CCUS offers in our attempt to address the dual challenge of providing more energy and reducing greenhouse gas emissions. We, therefore, need your help

to build that public support I just mentioned, so please take these materials, use them, and help develop your own story in a manner everyone will understand, like our key messages on this slide. The CCUS refers to the complete supply chain needed to capture, transform _____ use or store CO2, eliminating it from the atmosphere.

All credible future energy scenarios recognize that fossil fuels remain part of the total energy mix for the next several decades. CCUS is, therefore, essential to addressing the dual challenge of providing affordable, reliable energy to meet the world's growing demand while addressing the risk of climate change. The United States is the world leader in CCUS, and is uniquely positioned to deploy the technologies at scale. To achieve that deployment of scale, the U.S. government will need to reduce uncertainty on existing incentives, establish adequate additional incentives, and implement a durable regulatory and legal environment that drives industry investment. Commitment to CCUS must include a commitment to continued research, development and demonstration. At-scale CCS deployment could create a new industry, driving job creation and economic growth across the nation. An increasing understanding and confidence in CCUS as a safe and reliable mechanism is essential for public and policy stakeholder support. With that, we conclude our slides that we wanted to take everybody through, and we now want to open up to answer some of your questions. Thank you for your time today.

Kevin Great. Thank you to each of the panelists for those outstanding presentations. As we shift to the Q&A, I would like to remind our attendees to please submit questions using the Question pane at any time. We did receive quite a few great questions from the audience that we'll use the remaining time to answer and discuss. One of the first questions that I am looking at here is with regard to how these findings might be applied internationally. Obviously, this is a U.S.-specific study, but wondering, some of the methodologies, some of the findings, how those could apply to other countries or at a global scale.

Guy This is Guy. I can take that one on, and then probably Jarad would have a comment here, as well. I think as we've looked at the methodology that we used here, I think it's very informative in that it not only, again, addressed the cost, but it drove a very detailed discussion on the very specific policy instruments that are needed to actually drive CCUS. In some degree, what I've tended to see around the world is there are very high-level, overarching policies to incentivize CCS. But, in order to make this work, you're going to need to see very, very specific policies in a lot of the areas that we talked about in order to incentivize. I would suggest that this may be, if you will, a model for other countries to look at, not necessarily that they would follow this exactly, but it becomes an approach that they could use to assess their regulatory regimes, their economics in coming up with a similar type approach.

Jarad Guy, this is Jarad. I fully agree. I think this is a great example or template of really a regional approach to deploying CCUS at scale. I think this study provides food for thought for other countries, and the Clean Energy

Ministerial, one of our efforts is to sort of support this communication and this collaboration across the various countries in the world. When you look at this study, it's really a vision and a strategy for broad CCUS deployment. At the end of the day, you realize it has to be material and rational and realistic in the assumptions that are made. It's very important to understand the scale of the problem, and so a lot of the underlying data that Nigel and Guy talked to here, of course, is going to vary from country to country or region by region.

The distances involved are different, the costs to do work in those various countries are different, but I think this presents a very good template of a very strategic methodology that others can take to heart and then perhaps replicate or utilize in their own countries' context. It also provides a nice template for an effective way to communicate complex, multivariable problem issues, like a CCUS value chain from capture to transportation, to storage or end use simply and effectively. Our sincere hope is by getting the word out and talking about the study, we can help others think about how to do that in their countries or their regions, as well.

Kevin Great. Thank you. Jarad, just continuing along some similar lines there, how would you describe the way that this study was received by the energy secretary? Were there any particular points that were raised that might illuminate the audience to how this might be received more generally?

Jarad Yeah, so it was received very warmly and with great appreciation. The undersecretary had the leaders of this effort come on in and give him a private briefing after this was publicly announced and delivered to the secretary formally on December 12th of last year. There is keen interest. My office here just got a request last week, in fact, from the undersecretary to say, "Hey, give me some more information and the next level of detail about the specific recommendations that this study has." I think one of the best points of the study is it takes the collective wisdom, and a year and a half of work and debate and analysis and discussion across over 300 people, not just from the industry but everything that touches CCUS. It's really distilled down into this set of recommendations for, "Here is what the government could do, various policy tools that move the needle and accelerate and speed and broaden employment. Here is what the industry is ready to do."

I mean, I think from the U.S. government perspective, receiving those crisp, detailed and specific recommendations about what we can do to help accelerate CCUS deployment is one of the true gems of this overall piece of work, so that's the piece that I think the government is most excited about. Later this week, we have a broad, multiagency meeting, not just Department of Energy, but my federal government colleagues from our Environmental Protection Agency, our Interior Department, our Treasury Department, and there are a number of folks, again, that all touch on, "How can we work together to deploy CCUS?" There is an extreme amount of interest in the results and recommendations out of this study.

Kevin Great. Thank you. Another question related to access from our audience. Do you see transport and storage facilities as perhaps eventually open-access infrastructure to be used by many individual capture projects?

Guy Nigel, do you want to take that one?

Nigel Yeah, sure. Of course, _____ market-based system in many projects, capture facilities are in place, then a different way to operate, transport and storage aspects of course would be in that industry, of course, providing a service back into the system. But, of course, it takes a lot of pre-investment to develop those types of networks, and of course to kick-start and get projects up and running. Of course, you need the guarantees around supply of the CO2, as well as the guarantees around the off-take and transport and storage of CO2. Really, of course, as CCUS at-scale really gets off the blocks and gets started up, really we'll see and we have seen really a lot more point-to-point sourced projects really tackling their own issues, because then of course it's a lot easier to really work out your own solution in order to provide the assurance around being able to transport and store that CO2 once you've captured it.

Having a market-based system, where the CO2 is captured and then put across into various sources, yes, I think that could be a future state that the network really operates under, but of course getting from today to that future state will require a lot of project development, a lot of investment in infrastructure, and of course those business models, being able to really have the assurance that they can actually deliver into the marketplace and, of course, return the level of reward that those investments require. We're probably a little ways from actually seeing those develop given the guarantees that are required both on the capture side and also on the take side.

Guy Yeah, I would add to that. I mean, I think as you look at the phases of policy that we talked about, you're likely not probably going to see that in the Activation Phase. Most of what we saw there is going to be relatively pure sources in close proximity to storage locations, and it's likely to be more point-to-point type models. However, as Nigel suggested, once you start moving along that policy curve and you do get greater clarity on how to deal with things like transportation interfaces and long-term _____, and you see more incentives get into the system, I think most people that are on the study could envision trunk lines and hubs and multiuser type arrangements, but it's probably not in the first phases, at least.

Kevin Great. Thank you. Guy, you started to describe some of the evolution and how we've progressed through these phases. Included in that is perhaps a discussion of the actual technologies chosen for this study. I wonder if you could go into a little bit more depth on the methodology and reasoning for those chosen technologies, and perhaps touch a little bit on some of the more lower TRL technologies, maybe direct air capture, for example, its inclusion in the study and its role in the future as we progress through these phases.

Guy Yeah, I'll take a shot and then give it back over to Nigel. In terms of what we assumed in the study, and Nigel hit on it, it is proven technology implemented

at an nth of a kind. As we looked at the high purity sources, _____ sources that are 80, 90 per cent CO2 concentration or larger, the assumption that we made is that all that would need to be done is some type of dewatering, compression, and then put it into a pipe for either enhanced oil recovery or storage. On the less concentrated streams, and you kind of move from 80, 90 per cent to somewhere probably in the 20 per cent, the assumption would be that we use aiming technology on those streams to capture the CO2, and then again compression into a pipeline system to store. Nigel, you may have some additional comments or thoughts around lower TRL technologies.

Nigel

Thanks, Guy. Yeah, _____ _____ in that third volume within the technology sector, there is some great description and review of some of those earlier stage technologies that are really progressing from ideas through to lab, _____ pilot demonstration projects, and of course they include things like bio-energy with CCS, the use of membranes, absorption materials and _____ and chemicals, oxy-fuel combustion techniques, direct air capture – that was mentioned. Transport, also, of course looking at alternatives to the pipelines, and of course they do exist today at small scale, but how to really scale up and get some of those smaller sources into the pipelines by using perhaps the more flexible options around rail, shipping, trucks. Then, of course, when it gets to storage and utilization, non-EOR utilization. Of course, there is a lot of research and a lot of developments going on in that space, as well, low-carbon materials, as well as using CO2 in unconventional type oil and gas developments, other nonconventional formations producing _____ *[inaudible due to audio distortion]* into CO2 to produce low-carbon fuels and chemicals, so there is so much opportunity.

The opportunity set is large, and of course that just needs further support, further investment in order for it to really be able to deliver its potential in the future. That's where we did that analysis, and those down-arrows as you saw within the cost curve. I really do believe firmly that that commitment to continued R&D and technology can give potentially significant cost reduction in the future. We have, I think, a recommendation around the amount of investment for R&D over the next ten years, and we think there should be probably around a tenfold return if it's successful in delivering cost reduction, so a significant impact that technology can have.

Guy

One of the ongoing debates that we had amongst the participants of the study is how aggressively should we show improvement in cost as a function of technology, and we did include some. But, ultimately, we decided to go with _____ technology at nth of a kind deployment, and the logic there is that we did not want to, if you will, overpromise what technology could bring and somehow mislead what type of policy incentives would be needed if it doesn't come. If technology gets better, the incentives will drop and future studies will take that into account, but the collective view of the group was we needed to call it as we could see it today.

Kevin

Great. Thank you. There is quite a bit of discussion there about technologies, and perhaps going back to some of the earlier slides, there seemed to be a significant amount of engagement with industry. I wonder if you could also

touch on the involvement of the financial sector in this study, perhaps commenting on their views on CCUS as an investment opportunity perhaps?

Guy Nigel, you were probably closer to that one than I was, so you might want to comment there.

Nigel Yeah, I think, of course, the financial industry does see, and of course there is a lot of investment and a lot of _____ into other clean energy technologies by the financial community. Of course, a lot of funds are going into green and sustainable finance areas, and of course carbon capture, use, and storage really is one of those clean energy technologies that can deliver a lot of those global objectives. Of course, having an investable project, really providing clarity and certainty and guarantees around that was really, I think, what the financial industry really wanted to be involved in and understand from some of the major companies – equipment providers, procurement and construction companies, as well as the operators of different industries within the operation to get their viewpoints of, "How credible are these technologies today?" Of course, there are a number of large-scale, commercial-scale operations globally proving that this can be done, but how much more can be done today and what is required in order for it to be investable?

That's what they wanted, I think, to get insights on, and of course we provided that by having all of the various participants included in the study. I think they indeed see if there is a demand within the marketplace, if there is sufficient incentives and the technology is available today, yes, the technology improvements can come tomorrow. But, it can be done today and, therefore, it can be investable under certain circumstances. Of course, yeah, _____ there to look at how to actually make that money, that pool of capital available.

Guy They were also very helpful in taking a look at existing structures, like master limited partnerships, issuing private activity bonds, how to deal with tax equity issues, because these guys had a lot of experience, and not just oil and gas, but their experience in the renewable sector, as well, so just brought that feature and that understanding to the work we were doing.

Kevin Great. Thank you. In the interest of time, I think we'll have to move on. Thank you, again, to the panelists for that informative Q&A session. For any questions that we didn't have time to get to, we will connect with those attendees offline after the webinar. As perhaps a closing statement, if you will, I would like to provide each of the panelists with an opportunity to provide any additional closing remarks before we close the webinar. Perhaps thinking, too, towards the next step, you know, how do we keep the momentum of the study? How do we ensure that it inspires action?

Guy I think Nigel made this point earlier, and I'll couple it with something I said. This is kind of the second time that we've actually presented this study to an audience like this, so what we're looking for is feedback. How can we better describe what the study did, based on your knowledge and understanding of it? Second of all, the point that Nigel made is we're looking for champions in the CCS area, so the extent that this study can be used and helpful, please use

it. We're very enthusiastic about it but, as Kevin said, we need to keep the momentum going.

Nigel Definitely, please take the study, adapt it, understand it and adapt it. Ask us questions. We're here to help, and so please reach out, provide us input on your thoughts today, but please reach out. Also, if you have questions about adapting and modifying it and applying it elsewhere, then yeah, please reach out to any one of us. We're here to help, and I think that's definitely what the Clean Energy Ministerial CCUS initiative is there to do.

Jarad Absolutely. This is Jarad Daniels again, and on behalf of the U.S. Department of Energy, we again thank the National Petroleum Council for all of this time and effort and the work in this study, a year-and-a-half effort spanning over 300 people, as was mentioned. This is a tremendous amount of work and analyses, and it's all publicly available, so it's a great resource that can inform anybody's conversations, and for that were extremely helpful. As was already said, again, facilitating these types of conversations is what our Clean Energy Ministerial CCUS initiative is all about, and so if there is anything that we can do to help further this conversation with any of you that are listening, please let us know. That's a very good use of our time and effort. Again, thank you for your participation on this webinar, and Kevin, thank you and your colleagues at the National Renewable Energy Laboratory for hosting the webinar for us. It's a wonderful facility across the Clean Energy Ministerial to host these types of conversations with a very broad audience, so thank you.

Kevin Certainly. It's our pleasure. To close, one more time, if you would like to learn more about the initiative, please reach out at the e-mail displayed on the slide. For other news and developments, follow us on LinkedIn by following the link displayed here, and on Twitter, @ccuscem. Before we conclude, the CCUS initiative is excited to announce that our colleagues in China will be hosting the next webinar on Thursday, March 5th at 8:00 AM Eastern, 1400 Central European time. A formal announcement will be released via LinkedIn, Twitter, and various e-mail listservs in the coming months, as well. We look forward to providing yet another exciting opportunity to hear about CCUS developments and progress throughout the world. One more time, I would like to extend a thank you to our panelists and attendees for participating in today's webinar. We very much appreciate your time, and hope in return that there was some valuable insights that you can take back to your various organizations. Please enjoy the rest of your day, and we hope to see you again at future CCUS events. This concludes our webinar.