

# Framework for Carbon Capture, Utilization, and Storage (CCUS) in the Clean Energy Ministerial

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## Webinar Panelists

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**Vickie Healey** Today's webinar is focused on the framework for CCUS in the Clean Energy Ministerial. 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 located in the audio pane. If you choose to dial in by phone, please select the telephone option and a box on the right-hand side will display the telephone number and audio PIN you should use to dial in.

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Today's webinar agenda is centered around presentations on the New Clean Energy Ministerial Initiative on Carbon Capture Utilization and Storage. Before we launch into the presentations, I will provide a quick introduction of today's panelists. And then following the panelists' presentations we will have a question-and-answer session where the panelists will address questions submitted by the audience. Now I would like to introduce our speakers.

First up we have Jarad Daniels, who is the director of the Office of Strategic Planning and Global Engagement within the United States Department of Energy's Office of Fossil Energy where he is responsible for leading strategic

planning and techno-economic analysis for research development and demonstration of advanced coal and gas-based power systems.

Following Jarad, we will hear from Khalid Abuleif, who is Saudi Arabia's chief climate negotiator for the climate agreements since COP18 in 2012 and is a member of the country's delegation to the UNFCCC since 1991. Khalid is currently the adviser to the Saudi Minister of Energy, Industry and Mineral Resources on Sustainability and Climate Policy.

And with those brief introductions, I would like to welcome Jarad to the webinar. Jarad?

## Jarad Daniels

Thank you and something just happened to my screen so—oh, there we go. But I'm happy to be here today to provide some of the context for this webinar. Vickie, thank you for those introductions. For those of you in the audience, my plan will be to provide some background and framing broadly across the Clean Energy Ministerial and the work done to date by the Global Carbon Capture Utilization and Storage Contingency across many countries to sort of set the scene for where we want to go moving forward with this new CCUS initiative under the auspices of the Clean Energy Ministerial.

I'll take several slides to do that, after which I'll hand it off to my colleague Khalid, who will then detail and walk us through our plans moving forward where we see opportunity to maximize the benefit of doing this new scope of work and effort of work under the construct of the CEM. And then after that we can take questions and, hopefully, have a good robust discussion with all of you.

So, as you can see on this slide, the Clean Energy Ministerial is composed of a large number of countries plus the European Commission. It is estimated at about 90 percent of clean energy investment is contained in the countries that are members, and approximately three quarters of global CO2 emissions are represented by the energy ministers that engage through the Clean Energy Ministerial.

So, the Clean Energy Ministerial, it's a global forum to help promote policies to share best practices with the aim of accelerating a transition to clean energy, and one of the key aspects is it's a public-private collaboration. And under the CEM a number of partnerships and collaborations have formed between governments and the private sector and the non-governmental organizations and other groups as well. And there's, you know, the work goes forward in high-level annual dialogs and ministerial meetings, one of which is coming up next week in Copenhagen and Malmo, Sweden. And then there's year-round policy targeted technical initiatives and high-visibility campaigns.

And so broadly that annual set of work efforts that goes on under the Clean Energy Ministerial and then every year an annual ministerial that draws the world's global leaders in the energy sector from government and industry is really the construct and the opportunity, the platform that the Clean Energy Ministerial provides.

If you can go to the next slide, again, this has been going on for a while and has really become sort of the preeminent event, the leading meeting of energy ministers focused exclusively on clean energy over the last decade. The Clean Energy Ministerial was announced at its formation in December of 2009 by then Secretary of Energy from the United States Steven Chu, who announced he'd host the first Clean Energy Ministerial. And you can see on this slide where the Ministerials have been held in years past.

The take-home message from this slide is that the representation is geographically diverse, and that's an attempt to really focus on the key regional aspects in terms of employing clean energy technologies and options across the globe given the global construct and global challenges that we all face together.

So, on the next slide, walking forward again, the strategy of the Clean Energy Ministerial at large and what we're trying to do that Khalid will lead the conversation on with this new CCUS initiative is to come up with a distributed and shared leadership model. All of the efforts under the Clean Energy Ministerial are voluntary and collaborative. All of the governments and all of the organizations do not necessarily need to join all of the initiatives or efforts. It is simply voluntary and your government or your organization can engage and contribute where you see fit and where it's a good use of your time and effort.

One of the other benefits that the Clean Energy Ministerial has is it tries to be rather agile and light to bureaucratic overhead. As you can imagine, anytime you get 20-plus countries and the European Commission together, there is the potential for a lot of government bureaucracy that slows down real work and real on-the-ground progress. And so, the effort of the Clean Energy Ministerial is to minimize that overhead bureaucratic burden. There's no negotiated communiqués. There's really just a ground roots, bottom up collaborative effort, again, multilateral and multi-institutional, governments and the private sector coming together.

And I think that's how Khalid and I see a real opportunity to push forward CCUS technology and projects and programs under the Clean Energy Ministerial because it has that agility and because it has that broad reach across governments and the private sector and NGO communities as well.

So, on the next slide, again, just setting the framing here for where we are, how we got here and then hand it off to Khalid in terms of where we go into the future, last year at the eighth Clean Energy Ministerial—this was hosted in Beijing by our colleagues in China—there was a side event focused on CCUS. It was hosted and organized by our colleagues at the IEA, the International Energy Agency, and it was chaired by the Executive Director Faith Birol, and it was standing room only in this conversation.

You can see the photo here on this slide with Minister Carr from Canada, Minister Wongong from China, my secretary of energy, Secretary Perry and Faith and, again, well over 100 people in the room. And the topic of conversation was what are the factors that can actually attract investment—

clean energy investment, low carbon investment—to promising CCUS projects, to CCUS R&D opportunities and collaboration? And how do we accelerate investment in CCUS as a low carbon technology options? The investment in CCUS has lagged behind investment that we've seen globally in efficiency and renewable primarily in wind and solar investment.

And the question is how can we harness that and bring some of that to bear and drive down those cost curves and drive low carbon deployment through carbon capture utilization and storage similar to the success we've seen in some of these other technology areas? And so, this really put CCUS squarely in the conversation \_\_\_\_\_ [audio garbled] set of discussions.

And I think one of the opportunities that Khalid and I are, again, very excited about is that there's an opportunity here to broaden the focus of the Clean Energy Ministerial. Over the last eight or nine years it's primarily focused on efficiency and the renewable technology space. Last year at the CEM in Beijing, US Secretary of Energy Perry recommended that the CEM include initiatives and start up new initiatives on both CCUS, carbon capture utilization and storage, and civil nuclear energy.

And the framing that he used to put his case forward was that if all the global models that we all believe in and provide data and analysis to state that we can't meet our midcentury global energy and sustainable climate targets without a fair amount of CCUS and nuclear energy in that mix, then we're only talking about and framing our discussion around part of the solution. Wouldn't it be better and more efficient to include CCUS and nuclear in the conversation and frame the overall CEM approach consistent with, again, what all the major global climate models show and provide data and input on in terms of you need all of these technologies to meet our challenging global goals, whether it's two degrees, whether it's an aspiration or below two degrees.

And so that was introduced at last year's Clean Energy Ministerial and I'm happy to report today we've been working very, very diligently and earnestly over the last year to do our part to stand up the CCUS efforts going forward to maximize how we leverage what the CEM can provide in terms of functionality and the reach it can provide in terms of engagement beyond the folks that are already engaged in CCUS activities in a global basis and so that really set the stage going forward.

If you turn to the next slide, this conversation then continued in November on the margins of the IEA Energy Ministerial. Again, Faith Birol is a very strong supporter that CCUS needs to be prominently in the conversation in the global energy and climate discussions. He hosted another high-level summit focused on CCUS. It was co-chaired by Faith Birol and Secretary of Energy Perry. And, again, it engaged by energy ministers and leaders from the major energy companies around the globe, who got together and said, "Look, we really need to accelerate investment in CCUS and this needs to be a collaborative effort, again, between governments and the private sector in order to push forward the technologies and get actual deployment of CCUS

at scale consistent with what all of the models show is required to meet our midcentury climate targets.

And so, again, this was a very high-level renewed push squarely in line with the discussions at the last CEM. And, again, I'm not going to read the list, but you can see that the companies represented in this discussion were truly some of the leaders in the energy sector on a global basis.

And then on the next slide this conversation—and, again, Khalid and I have been front and center trying to frame this and chaperone this global effort moving forward on behalf of our countries, the United States and Saudi Arabia. There was a Carbon Sequestration Leadership Forum Meeting in Abu Dhabi hosted by Minister Al Mazrouei from the UAE. And the CSLF, the Carbon Sequestration Leadership Forum, is another global organization that was focused just on CCS or CCUS, carbon capture storage, carbon capture utilization and storage. It was initiated in 2003 by a number of countries. And on my next slide I'll show you the overlap between the CSLF countries and those in the Clean Energy Ministerial.

But over the last decade, the Carbon Sequestration Leadership Forum has been pushing for global collaboration and coordination to advance CCS technologies and supporting policies. And I think there's a real opportunity to leverage all the good work that's been done over the last decade under the CSLF and expand from that moving forward under the Clean Energy Ministerial. And so, Khalid and myself and all of our colleagues in many countries had conversations over the last year to help us determine what is best to be done moving forward remaining in the CSLF? How do we leverage that and what new opportunities with this new initiative under the Clean Energy Ministerial provide?

The Clean Energy Ministerial has a slightly broader set of countries and, again, it really frames that overall low carbon, global climate conversation more holistically to include efficiency and the renewable technologies and now moving forward carbon capture utilization and storage and nuclear as well.

And so, at the CSLF meeting in December, again, hosted by our colleagues Minister Al Mazrouei and the UAE, again, the meeting focused on advancing the business case for CCUS. Many of the low carbon technologies have merits on their own. Carbon capture and storage is one of the ones that you only do for the sake of climate change mitigation. Absent a price on carbon, it's difficult in many countries to have and find a positive business case for applying carbon capture and storage.

And so, again, the global conversation: What can we do to advance the business case? What supporting policies do you need to enable CCUS to take off similar to the supporting policies we've seen success for around the world with wind and solar, for example? So, again, finding opportunity to really frame that conversation broadly.

Every year under the CSLF there's a ministerial communiqué that comes out the CSLF ministerials are every two years. And so, when in this communiqué the key points are listed on this slide and, again, really the need for policy support from the governments for an all-of-the-above approach to solving our energy and climate concerns globally that there's no one-size-fits-all technology. We need all of these technologies and efficiency working together demand-side and supply-side to really achieve our overall global low carbon and clean energy goals.

We need to find a way to leverage success of the operational CCUS projects and springboard forward from there. Right now, there's 21 operating large scale, meaning on the order of 1,000,000 tons of CO2 capture per year, CCUS projects that are up and operating well on a global basis. There's a number of them in my country here in the States. There's some in the Middle East and Saudi Arabia and the UAE. There's a number over in Asia. There's a large number of projects across both the power sector and industry.

But going forward, there's sort of a lull in the pipeline of projects that have been announced, new projects moving forward. And so, I think there's a real opportunity that we have to try to expand on those and that's part of what we have that Khalid will talk through in terms of our scope going forward under the Clean Energy Ministerial.

There's growing interest in the global CCUS community finding opportunities to utilize the CO2 in some market opportunities that exist. Currently CO2 is used for enhanced oil recovery in several regions around the world. For example, in the United States we have been using CO2 for enhanced oil recovery in the Permian Basin down in Texas since the 1970s. The United States has several thousand miles of CO2 pipeline. We move on the order of 70 million tons of CO2 on an annual basis in the United States, and that works just fine as a mature industry.

But there's opportunity to do advanced oil recovery in many other regions of the world. In the Middle East this looks economically attractive. In China this looks economically attractive, for example. But there are also other opportunities to use CO2 as a feedstock for some chemical production and there's an opportunity to explore the science and technology behind that.

There's also an opportunity and the communiqué pointed out we, as a global CCUS community, can do better to expand our stakeholder engagement and really let people understand where CCUS can fit into the overall global efforts to meet our sustainable energy goals and get to our midcentury climate targets. And then, again, I think all of us, no matter what our day job is, there's always room for improvement to engage the public on what we do. And with CCUS in specific there's a clear opportunity to leverage all of the communication platforms that the Clean Energy Ministerial provides, such as this webinar today, to do exactly that.

So, on the next slide if we can turn there, hopefully I'm giving you a good idea of sort of the background of CCUS at large and getting us to where we are moving forward. This is just a diagram to let you see the overlap between

the members of the CSLF and the Clean Energy Ministerial. Many are the same ones. It's our understanding the Netherlands will formally join at this next week's Clean Energy Ministerial and then the Clean Energy Ministerial will be up to 26 members including the European Commission.

And, again, a lot of the leadership on a government basis for carbon capture utilization and storage are active in both the CSLF and the Clean Energy Ministerial. So, Khalid and myself and our colleagues in a number of countries were, I think, very well positioned to coordinate these efforts to make sure we're not duplicative of the good work already going on but to really find those opportunities for value added to the existing body of effort and see how do we maximize the good and the benefit of standing up this new CCUS initiative under the Clean Energy Ministerial?

So, on the next slide I believe this is where I say I hopefully have set the stage and giving you an appreciation of the work done to date and how this new effort under the Clean Energy Ministerial sort of fits into the broader construct. At this point, I will hand it off to my good colleague and friend Khalid, who will now walk you through a set of slides that detail our plans moving forward. Hopefully, what we have on the slides here will frame those conversations well. And then, again, we'll be open and happy to have a good robust question and answer set of discussions after Khalid's presentation over the next slides.

So, Khalid, the floor is yours.

**Khalid Abuleif**

Thank you, Jarad, thank you. And, dear colleagues, what Jarad has done so far is frame the whole issue and showed how can we meet the challenges that we have with the targets and aspirations that we have to meet as we move forward. And we also saw from the discussion the importance of making that we tap into any opportunity that we have and to make sure that emission does not move to the atmosphere. I think that as we have said earlier that, yes, we have started with energy efficiency and renewable. But we really do have and do see that there is great opportunities and also tapping into other technologies such as carbon capture utilization and storage as well as nuclear.

So, in this part of the presentation I will focus more into the Clean Energy Ministerial initiative that we have proposed, which is one carbon capture utilization and storage. And then I will walk you through where we are. How do we see this being done there? Who are the partners that we will look for or advancing that business model as we'll then share with you our expectation and our hopes for CEM 9 as well as the side events that we have. Next slide.

Now as a first starting point, I will focus on those initiatives or those activities that we really hope to see be looked at and this CEM activities. As Jarad said earlier, we looked at all other initiatives and it was extremely important that we build on what we already have whether the emission innovation or in carbon sequestration leadership or other initiatives that exist in this area to see how we can complement that with other activities that would also demonstrate greater value for making this technology functional and commercialized as we move forward.

So first we looked at expanding the spectrum of clean energy technologies, as Jarad said earlier. Then we wanted to see how we can create a sustained platform for bringing the private sector and the governments and the investment community together to ensure that this business model moves forward.

Also, we were hoping to see how we could facilitate identification of all that between the near term and the long-term investment opportunities that we should look at to improve the business case for this important technology. We also feel that the CEM is an excellent platform to help in disseminating emerging CCUS policy, regulatory and investment best practices as we move forward. So, all these activities could be brought under the CEM activity and at the same time will not be duplicating work that we have in other areas as we move forward. Next slide.

Then we looked at those potential partners that could also help in building that business model. We think from the government side we saw great interest from many countries such as Canada, China, the European Commission, Japan, Mexico, Netherlands, Norway. We here in Saudi Arabia are also very much interested in this as well as our neighbors United Arab Emirates and United Kingdom and United States has always showed a great interest in seeing these technologies move forward. So, we're hoping that we will build above and beyond these countries and bringing them part of this program.

On the industry side we're really looking for most of the industry and we see greater opportunity for industry because that's the only option for a district to decarbonizes as we move forward in the future. And we believe that carbon capture and storage is going to provide that opportunity for them to advance. So, we look also for the oil and gas community to be very, very much active. They have shown great interest as part of this discussion.

We're also, as Jarad said earlier, hoping to see many financial institutions get interested in this. We are working with many right now and we're hoping that we can bring on board some of the multilateral development banks that could be also added into that discussion. Also, we hope that organizations such as CLF International Energy Agency, basically the IEA greenhouse gas R&D program and the Mission Innovation, the Global CCS Institutes and the Oil and Gas Climate Initiative would be organizations that could really advance these business models and help in proving this platform.

We're looking also for other initiatives within the CEM itself like 21st Century Power Partnership and Clean Energy Solutions Center to be also part of this initiative and advancing its goals as we move forward. Next slide.

Now we're looking at the first year of action and we're going to focus the first part of our action on this initiative or knowledge and knowledge-sharing and learning and exchanging experiences. We do have—we could do that through best practices in in-country work such, for example, we have the CEM Clean Energy Solutions Center in the United States that could also help. For example, the service of Ask An Expert could be a service that could provide that help. Also, there is also in the Clean Air Energy Solution website there is



many items and many elements there that could really be tapped into for many of the experiences and then lessons learned out of these actions that we did have.

Also, we would hope to establish an industry advisory body to provide regular dialogue with key energy ministers on CCUS progress and priorities. We really do think that the policy side is about to be extremely important in moving this business model forward, and we're hoping to be a mission point to do so. Also, we are hoping to look forward to conducting workshops with the industry and policymakers to identify promising CCUS opportunities and also bring in on this platform from collaboration from the different chain to this technology that could really help in advancing that model forward. We're looking also for feasibility studies and assessments as part of this action that we have in our first year. Next.

Now other areas that are also areas of focus that we'd like to see develop as we move forward also recognizing that we really need to build above and beyond what we already have on the other platforms. But we were really looking at also areas like policies, road maps, looking at financial models for most of the work that we have, looking at also feasibility studies, infrastructure discussions and requirements and needs, regulations, stockholder engagement and also standards and best practices as we move forward. So, these are also some of the focus areas that we hope to be touching upon as part of our work in that important organization. Next.

Now, going to the ninth Clean Energy Ministerial, first I think we would like to formally launch the new CCUS initiative at an official side event on the side of the CEM9 activities. We would like to also during that ministerial to highlight recent CCUS developments, opportunities and the plans for this initiative to over establish initiatives.

Also, we look for supporting ministers, you know, notes and how we can launch our future plans in the plenary discussions that we have in these sessions. So, we really do have great hopes during the first—the upcoming session CEM 9. And I think by doing those activities, we will be hopefully hitting the ground running as we move forward. Next slide.

Now, there will be also a side event that will be held on CEM 9 and this will be on Thursday, May the 24th. And basically, that one-hour-long side event that will be co-chaired by the minister from Norway and also the executive director of the international energy agency to look through at those opportunities that we have with regards to how we can advance the role of the government leadership in pushing this forward as we look at the networks and also at the possibility of having the industry and financial sectors partner in that effort. That side event will provide, no doubt, a good model for us of engagement between the private and the public sector. And we really do look forward to that engagement and the collaboration between the two in advancing this important technology. And next.

With that, I will thank you very much and I would say that we're really ready at this stage to, hopefully, launch this important initiative during CEM 9 and

we will forward to any support or any government, industry or active participation from all those partners and make sure that we are building that business model for this evolving technology. Thank you very much.

**Vickie Healey**

Great. Thank you to each of the panelists for those outstanding presentations. So, as we shift to the question-and-answer session, I'd like to remind our attendees to please if you have questions, submit those questions using the Question pane and you can do that any time. So, we have had some good questions that have come in, and I will jump over to those and ask our presenters if you could address these questions as I present them. So first up, what are the current economics for carbon capture, utilization and storage? It's really kind of a three-part question. How expensive is it and how does it compare with other low carbon technologies?

**Jarad Daniels**

This is Jarad. Maybe I'll start with an answer and Khalid can join in if I leave anything out. Good set of questions in terms of how you frame a question of how does this fit in in terms of costs versus other low carbon options. There's no one-size-fits-all solution. In the power sector, if you're looking at carbon capture, utilization and storage for decarbonizing, say, a coal power plant, right now the technologies are on the order of \$60.00/ton of CO<sub>2</sub> captured. But there's R&D in the pipeline that could drive that toward a figure of merit on the order of \$30.00/ton of CO<sub>2</sub> capture, again, for the power sector where CO<sub>2</sub> is dilute in concentration coming out the back end of a coal-fired power plant. The economics are slightly different if you look at natural gas.

If you look at real the low hanging fruit opportunities are for CCUS in the near term, it's really in the industrial sector for several reasons. A lot of industrial processes, such as ethanol production or natural gas processing, have higher concentrations of CO<sub>2</sub> in their working fluid streams. And because of those higher concentrations, it's more efficient to capture the CO<sub>2</sub> and separate it from the rest of the working stream gas. So, there are many opportunities, for example, in the US and US economics. There's tens of millions of tons of CO<sub>2</sub> from industrial processes out there, point sources, where the capture costs are far less than \$30.00/ton with currently available technology. And so, one way to look at it is there's low hanging fruit that we should harvest primarily in high concentration industrial sources of CO<sub>2</sub> and those are perhaps some of the earlier opportunities to deploy CCUS.

That—those costs then have to be compared with the other options. In the power sector, obviously, there's other choices to be made if you're putting new generation into service. Then you have to then compare the all-in costs of, say, renewables or nuclear versus a fossil asset with CCS. And really to do that well, you have to do that on a system lifecycle basis.

Another way to look at what's the current economics of CCUS would be to say if you take a step back and you look at a global basis to get to our midcentury climate targets, how does CCUS fit in? And if CCS is part of that solution set, how does that change the overall cost to achieve our midcentury 2050, 2060 two-degree scenario goals, for example?

The IPCC, International Panel on Climate Change, in their fifth assessment report that they did several years ago, they looked across all the global models and they basically flipped the switch in the models and said, "If we assume CCS is not available as part of that low carbon technology solution set to deploy in the models, what happens?" And there were some interesting things that came out of that. Many of the models that the IPCC looked at could not close numerically. They could not get to a two-degree solution without CCUS being part of that technology option set full stop, so that's one way to look at it.

Another way to look at is of those models that the IPCC ran that could find a solution to two degrees without CCS, the average increase in cost for that overall global solution to get to a two-degree target was well more than double the cost with having the models have CCS be available. And so, I think a couple of the reasons why that is, No. 1, it enables that low-cost solution in the power sector. But also, it enables deep decarbonization in industrial processes where there's simply no other technology solution. And, so, if you are calcifying cement, that process gives off CO<sub>2</sub> just due to its process chemistry, and CCS is really the only technology that can decarbonizes that process, the same with steelmaking.

And so, again, right now you can look at economics—and this is a long-winded answer, but I'm very passionate about this—somewhere on the order of \$60.00/ton in the power sector, less than \$30.00/ton of CO<sub>2</sub> removed from industrial sources. But, again, in a more global construct if you don't have CCS as part of the solution, most of the credible global models suggest the overall price to get to our midcentury targets would more than double versus if CCS is part of that overall solution set.

Khalid, hopefully I covered most of it. I don't know if you want to add anything.

**Khalid Abuleif**

After that, Jarad, just to add to that and if you posit that this model can be economically feasible, we wouldn't have some commercialized projects that took place. As a matter of fact, as we all know that there are almost 17 such projects that exist at this stage. And we all know that these projects are responsible for capturing almost 57 million tons of CO<sub>2</sub> per year so imagine, imagine the magnitude of that number.

Now, also imagine if you are in a country where your economy is highly dependent on fossil fuel and without the carbon capture and storage and without making sure that this at the end of the day, you know, the CO<sub>2</sub> part of it becomes valuable, and you can really take that and utilize it and make sure that you are gaining an opportunity out of it. Then imagine the cost that such country is going to have as part of any solution as we move in the future.

So, you're right, Jarad. No doubt without really working hard and making sure that we have more projects and we will not be able to really bring the cost and we will not be able to meet, as you have said, the IPCC goals that they have set.

**Jarad Daniels**

And maybe I'll just add one more item here that, again, I think globally in a long-term sense the value proposition economics for CCUS are very promising and very good, especially if you assume we need to meet our midcentury targets and the models are correct. And that is near impossible or extremely expensive, more than double to get there, if CCUS is not part of that overall solution.

I think the economic challenge that we face in the near term is that CCUS technologies are very capital-intensive and they require economy of scale. And so, I think that's the collective challenge that, hopefully, we can address with this new CCUS initiative. How do we drive down those costs for the technologies? And in addition, how do we bring financing to it, again, given that long-term necessity and good value proposition?

**Vickie Healey**

Great, thanks. Actually, Jarad, that's the perfect segue I think into the next question that we have coming in from our audience, which is are there specific wants or needs for support from the private sector such as related to projects, policy, communications, things of that nature?

**Jarad Daniels**

Oh, absolutely and I could write—read that question two ways: what is the private sector want and need from the government and then what does the government want and need from the private sector? And I think the short answer is both of those contingencies are extremely important. The government would like—at least from the United States perspective, we really want this to be a private sector investment to CCUS as a low carbon technology that is in their best interests to find and drive toward the business case for CCUS such that the private sector based on the economics of the projects will invest in CCUS projects. And, again, as I just mentioned, these are very large, usually capital-intensive projects.

And so, what the private sector needs is they need stability. They need security knowing that there are stable policies that will value CO<sub>2</sub> emission reductions. They need to have stable policies and markets that say if they're going to use that CO<sub>2</sub> as an input to drive other economic processes such as enhanced oil recovery or some of these other CO<sub>2</sub> utilization options that those markets are stable and they can get a good return on investment for their shareholders.

And, again, they need to understand that if they invest in CCS in the power sector that those power sector markets will still be stable and that those units will be able to make a positive return and stay operating for the life of the project, which again in many of these long-term, long-lived capital products such as CCUS, these are tens of years. And so, it's been challenging with some of the uncertainty with the lack of a carbon market or an effective price on carbon. Again, CCUS is one of these technologies where we've seen good forward progress in the United States, in the Middle East and Saudi Arabia and the UAE and in China and elsewhere because of the opportunity to take advantage of the economics of enhanced oil recovery and an off-take for the CO<sub>2</sub> molecules, and people are willing to pay for that because there's an economic business case.

But I think going forward, both the public sector and the private sector, the more we can do to provide that policy parity with other low carbon technologies to provide that surety that's required for businesses to invest in CCS projects, that's in everybody's best interests. And, again, that's what Khalid and I and others have set out to do under this new initiative under the CEM.

**Vickie Healey**

Okay, thank you, Jarad. Khalid, did you have anything to add or should we move to the next question?

**Khalid Abuleif**

No, we'll go to the next question.

**Vickie Healey**

Okay, great. Thank you. And this next question actually kind of builds on some of the things you've already talked about, but the question is what are the key impediments to large-scale deployment of CCS? And how can emerging environmental markets, carbon markets for example, work to incentivize deployment?

**Jarad Daniels**

Khalid, I've been talking a lot. Why don't you take the first stab at this one?

**Khalid Abuleif**

Well, I think no doubt that making sure that investments are available and that there will be investment in that side is not there. I think that would be one of the impediment that we always have. Another is incentives and incentives in particular by governments to make sure that the investments are going to be available for that technology to move forward. So, I think those two very important impediments that we have is really I think we can do a lot. I think we can move them forward. If we can put together the investments and policy as well as the collaboration between all those players, I'm sure that we can find ways and means to resolve it as we move forward. Jarad?

**Jarad Daniels**

Yeah, again, I echo Khalid's comments and, again, I think finding ways to get past first-of-a-kind projects is in our best interests as a global CCUS community. If you look at some of the projects that have stood up over the last few years and are operating well and, again, taking on the order of 1,000,000 tons each out of the atmosphere of CO<sub>2</sub>, you know, all of the analysis around those projects shows that if they went from a first-of-a-kind project to a second-of-a-kind, there's on the order of 20 or 30 percent cost reduction just because of the lessons learned in that first-of-a-kind project, and I think you see this across the technology space. There's always a curve like that.

And so, I think the collective challenge here is to say how do we accelerate these deployments? How do we bring stability and certainty to allow private sector investment in these projects and really drive down that cost curve and drive our broader deployment of CCUS projects sort of two ways in parallel? One, learning by doing and driving down the cost that way and then, two, in parallel continuing to collaborate on the research and development?

You know, if you look at an overall CCS project, the capture and compression costs of capturing the CO<sub>2</sub> out of that working fluid stream and compressing it, that's on the order of 80 percent of the cost of the overall

system. And there's a real opportunity to through advanced technology R&D to really drive down those costs which, again, at the end of the day helps find and deliver that positive business case and speed deployment. But, again, I think overall the backdrop of supporting policies and stable policies in a low carbon sense define good business opportunities to stand up these projects globally. That's what we're seeking here.

**Vickie Healey**

Great, thank you so much. So, building on what you just spoke to, Jarad, about R&D a question came in how could or should the CCUS research community get involved in the Clean Energy Ministerial? Any thoughts on that?

**Jarad Daniels**

Sure, that's a great question and, again, the global CCUS research community is then actively collaborating ever since we've been working on CCUS so going on two decades. That is chaperoned right now under the auspices of the Carbon Sequestration Leadership Forum. They have a technical group there that really coordinates a lot. In the last several years Mission Innovation stood up and all of our countries, on the order of 20 of them, got together and said, "How do we collaborate better under the auspices of Mission Innovation on reducing the costs of carbon capture and improving the technology?"

There was a big workshop that was hosted by the US and Saudi Arabia here in Houston last year. A report will be forthcoming and publicly made available early next week by our colleagues that drive the Mission Innovation effort highlighting where are the key areas and opportunities to focus our R&D efforts? And also, what are the best mechanisms where we can collaborate even more efficiently and effectively than we're doing now?

Right now, there's a number of multilateral collaborative efforts, some under the CSLF, many under the International Energy Agency or the IEA's Greenhouse Gas Program. And, again, our colleagues that work the Mission Innovation space have identified even additional mechanism where a number of countries can collaborate. I think it's two- or three-fold. One, it's early stage R&D on promising modeling simulation and sort of bench top chemistries and research. There's another strand of conversation when you get up to the pilot scale and you need to test your technologies at scale and find the devil in the details when you scale up any technology. There's good collaboration across a number of our countries now, and I think there's good opportunity to expand and leverage that moving forward.

The Clean Energy Ministerial is really focused on sort of higher-level policy conversations. How do we engage the private sector? How do we engage the financial community specifically to open up some of their low carbon financing mechanisms to include CCUS in their portfolio of low carbon project finance? And so, I think this will be—we'll have to coordinate closely the work that gets done under the Clean Energy Ministerial with the more R&D-focused nature work that gets collaborated under Mission Innovation and the CSLF's technical group and the IEA's efforts in the space as well.

But the bottom line is there's plenty of good work to go around. I think the CEM effort is unique, again, is we can help frame the broader global energy



conversation in the appropriate manner to include CCUS and then, too, the convening power that the Clean Energy Ministerial has. A lot of the developing nations are members of the Clean Energy Ministerial. A lot of the financial community and NGO community finds comfort in engaging through the Clean Energy Ministerial, and I think that can be brought to bear positively on how we can use the CEM to really leverage R&D and policy and investment space sort of all in a combined holistic fashion.

**Khalid Abuleif**

Just to add, Jarad, also I think no doubt that the R&D community is basically the basis for the success that we had in this technology, but we must recognize that CCUS has passed that point. I think we really need to have some of the projects that has already been in private phase and many of the projects that has already went into the commercial phase and they succeeded to do that commercially.

Now so some of these successes that are already on the ground, which really require the help of platforms like Clean Energy Ministerial should continue and should be pushed into a good business model to really help in managing the emissions question. However, also in addition to that, there are greater money opportunities that we need to tap into because what we're doing right now is not enough. I think on the utilization side in particular I think we really need to push the envelope on the R&D side and make sure that we come up with those ideas that could really provide the industry with opportunities for utilizing the CO<sub>2</sub> as we move forward in the future.

So, I think we have a greater role. I think within Mission Innovation, as Jarad just said, we have greater opportunity to advance new areas and new opportunities but also, we in CSLF I think we can take that and scale it up looking at how we put bring it ready for commercialization hopefully in the CEM part of it. So, we do see that there is a clear connection and the clear chain going from the Mission Innovation to clean carbon sequestration be the sharp forum and its role in advancing the work there as the Clean Energy Ministerial in making sure that we bring in the stakeholders together and build the business model for it to function as we move forward.

**Vickie Healey**

Super. Thank you both. I think we have time for one more question before we close things out. And for those of you who are submitting—we've had a ton of questions coming in and we'll try to address these offline after the webinar so we apologize if we're not able to get to your question. But for this last question, let's talk a little about the public view and how do we deal with or build public acceptance of CCUS issues in especially the major emitting countries?

**Jarad Daniels**

That's an excellent question and probably a great one to end on. I think we can all do better jobs in terms of engaging the public on energy and sustainable development in general, and our conversation on CCUS is certainly a part of that. I think providing the understanding that CCUS is part of that technology-enabled solution that all of the models suggest we need all of the above in order to meet our sustainable energy goals. We need as much efficiency both demand side and supply side throughout all facets of our economy. We need to push in as much renewable energy into our power

sector as we can. And we need to decarbonize our industry and our transport sector and we simply, again, according to all the models, we can't get to where we want to be without CCUS as part of that equation.

And I think framing that conversation and really having those conversations with all sorts of the public and stakeholders, we can all do, you know, spend an entire career doing that. There's so much good work to do with that education starting with the youth and all the way up through all facets of our society. But, again, I think framing the conversation holistically is the most efficient way to do that.

Again, if most of our emissions can come down over time, the power sector has many options, renewables, efficiency, nuclear, CCUS. Some of the facets of our society don't have that many options. So, when you look at the carbon-intensive industries and about a third of our CO2 emissions globally come from industry: steel and cement and concrete. Assuming our societies are going to continue to use those to build our built environment, CCUS is, again, really the only technology that can deeply decarbonize those industries.

And so, doing that public outreach and education and letting folks better understand how CCS, CCUS fits into that overall low-cost solution set to providing our energy security, to providing our global environmental sustainability we trying to do that. I think CEM is part of that effort and we can do that through the convening power of the Clean Energy Ministerial. I think the IEA and Faith Birol personally is committed to doing this and I think the IEA has done a wonderful job leading that conversation and we can leverage the IEA's efforts as well in our new initiative here.

**Khalid Abuleif**

Just to add for one second, if we know and look at the challenge that we have and we all know that we need to keep those greenhouse gases out of the atmosphere and I don't think from a public view, if you look at it, any opportunity that will be there to move those emissions away I think should be an opportunity that should be looked at positively because at the end of the day it will raise and increase our ambition in doing what we need to do to address the huge challenge that we have in front of us.

**Vickie Healey**

Great. That's a great way to end the webinar. Thank you so much. So, again, one more time thank you again to the panelists for that very informative question-and-answer session. And for any questions, again I'd like to just repeat, that we did not have time to get to we will connect with those attendees offline after the webinar and address those questions that you asked. So now I'd just like to provide the panelists with an opportunity to offer up any additional or closing remarks you'd like to make before we close the webinar?

**Jarad Daniels**

Vickie, this is Jarad. Maybe I'll go first and be very brief, again, just to thank everybody in the audience for your time and effort and participation today in this webinar. Hopefully we've done a good job of describing to you the background in our efforts going forward to stand up this new CCUS initiative under the Clean Energy Ministerial. We would welcome any and all of your engagement in this effort as we move forward. We're happy to answer and



have a dialog with any questions or conversations you'd like to have, and I think there's a mechanism to do that. And so, again, just a sincere appreciation for joining the webinar and we look forward to future conversations with you so thank you.

**Khalid Abuleif**

And from my side thank you, Jarad and everyone that has been there. And I have to say that without you also participating and making the difference, this would not succeed. So, we really do need everyone's participation and everyone's engagement for this to succeed. And I'm sure with that I thank you all for giving us an opportunity to come here and explain this today.

**Vickie Healey**

Great. Thank you both. So, with that I'd just like to extend, again, a thank you to both of our expert panelists today and especially a very hearty thank you to our attendees for participating in today's webinar. We very much appreciate your time and your interest and we hope that in return that you have received some valuable insights that you can take back to your ministries, departments or organizations and to your networks. So, with that, please enjoy the rest of your day and we hope to see you again at future CCUS events. This concludes our webinar.

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