Title: Hearing of the Subcommittee on Energy and Water Development of the Senate Appropriations Committee - The Reuse of Carbon Dioxide From Coal and Other Fossil Fuel Facilities
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Hearing of the Subcommittee on Energy and Water Development of the Senate Appropriations Committee - The Reuse of Carbon Dioxide From Coal and Other Fossil Fuel Facilities

Chaired By: Senator Byron Dorgan (D-ND)

Witnesses: Scott Klara, National Energy Technology Laboratory, Department of Energy; Jeff Muhs, Utah State University, Executive Director, Center for Biofuels, USU Energy Laboratory; Brent ConstantEO, Calera Corporation; Marjorie **Tatro**, Director, Fuel and Water Systems, Sandia National Laboratories

SEN. DORGAN: I'm going to call the hearing to order.

This is a hearing of the Energy and Water Subcommittee on Appropriations in the U.S. Senate. Today we're going to hold a hearing on the beneficial reuse of carbon dioxide, CO_2. The $3.4 billion for carbon capture and sequestration funding that was put in the stimulus program or the economic recovery program includes beneficial use in that solicitation.

And one of the reasons we wanted to have this hearing is I am convinced that we will need to continue to use coal in our future. Fifty percent of the electricity comes from coal. The question isn't whether we use coal. The question is how.

And my belief is that we will continue to use coal but in a different way. We need to make a significant effort to de-carbonize coal, and the question is what do you do with that carbon?

Perhaps some will be used for enhanced oil recovery. Already that is the case with a project in North Dakota and that makes a lot of sense. Some will be sequestered somewhere, and some will be used for, we hope, beneficial use. And that's the purpose of this discussion.

We need to look at a wide range of options for sequestering CO_2 and using CO_2. The issues that we'll discuss today increase those options. We know that there are benefits that can come from storage in soils of CO_2.

We have a project in North Dakota sponsored by the North Dakota Farmers Union which has established carbon credits on the Chicago Climate Exchange. They're the fifth -- the largest, rather, aggregator of agricultural carbon credits on the CCX, with more than 5 million acres enrolled in 31 states.

But there's been growing interest and need to support carbon capture and storage on a very large scale, both in this country and around the world.

The Department of Energy Technology Laboratory study shows that if the U.S. emits about 2 gigatons of CO_2 a year from coal-fired power plants, then there could be more than 40 years' worth of storage for enhanced oil and gas recovery, more than 35 years' worth of storage in un-mineable coal seams, perhaps 500 to 1,600 years' worth of storage in saline aquifers.

And North Dakota, as I said, has played a significant role here, with the Great Plains synthetic fuels plant. I was just there a week and a half ago. They strip off 50 percent of the CO_2 from the facility. They compress it, put it in a pipeline, shipping it to the Weyburn oil fields in Canada for enhanced recovery. And they're sending about 3 million tons a year for that purpose.

This leads us to the issue of beneficial reuse and the primary focus of the hearing. When we talk about beneficial reuse, it's important to make a distinction between the terrestrial offsets that absorb CO_2 from the atmosphere and process that directly -- captures CO_2 from coal and other fossil-burning plant emissions and convert it into usable products.

Well, algae biofuels are an example, I think, of beneficial reuse. We have a chart, I think, that shows algae tanks. Algae are the fastest-growing plants in the world. They can double their bulk in a very short period of time. They can grow in wastewater and convert CO_2 into a liquid fuel that's compatible with our existing fuel structure.

This is an algae tank chart. We have stopped research on algae for about 15 years, I believe, and we began in this subcommittee to start that research once again.

The circumstance in this case should be to take a product such as CO_2 and turn it into a usable product. We have a project that I looked at in Arizona where they are taking the CO_2 from the flue gas, and growing algae, and then harvesting the algae for diesel fuel. Well, that's a beneficial use.

There are other projects that have been described to me, including patents that would turn CO_2 into a product. One product similar to concrete -- harder than concrete, they say, with significant value -- a beneficial use, because that would capture all of the CO_2.

Another company came to me and described a process by which they create chemically -- I believe it's nitrogen, hydrogen and baking soda and the baking -- the equivalent of baking soda contains all the CO_2.

There's a lot of interesting ideas out there. My hope is that the funding that we're making available will allow us to scale up a range of these ideas to find out what works at scale, what is the silver bullet, if there is one, and let the free market then beat a path through their door to say, "You've demonstrated something that we're very interested in and want to do."

This chart, by the way, shows that some folks came to my office with a plate of cookies and said we want you -- this comes from coal -- cookies from coal. But in fact, it was a description of storing CO_2 in what is commonly called banking soda.

So beneficial use of CO_2 -- what are the ideas out there; what might or might not be the case; what will we find? Will science and technology and research unlock the mystery of how to do this at scale and in a way that perhaps reduces the price of carbon that is limited by legislation, reduces that price to near zero? Who knows?

And so we'll hear from four witnesses today.

Senator Tester.

SEN. JON TESTER (D-MT): Thank you, Mr. Chairman. Only in America can you make cookies out of coal.

SEN. DORGAN: That's right.

SEN. TESTER: That's good. Hey, I don't want to repeat what you said, but I fully agree with the fact that we are going to be burning coal for a long, long time. Montana happens to be America's version of the Saudi Arabia of coal. And we need to figure out ways to deal with the CO_2 issue.

I think everybody understands that.

I guess the only thing I will ask of you guys -- and the chairman alluded to it -- is how close are we to commercialization on each one of the things that you're going to talk about. I think that's really what's critically important as we try to address the CO_2 issue and as I get people from the state of Montana coming into my office every day saying, "We can't do this. We can't deal with the CO_2 issue. We've got to keep doing business in the same way."

What that tells me is that there's not a lot of known options out there, and we need to make them known -- the options that are real.

So with that, thank you, Mr. Chairman, and look forward to the hearing.

SEN. DORGAN: Senator Tester, thank you very much.

As you say, Montana has a lot of coal. So does North Dakota. And as I've indicated before, I don't think we're going to see a future without coal.

I think we're going to see a future in which we use coal differently, and that is de-carbonizing the use of coal. The question is can we do that in a manner that provides benefits, or is it just a liability to try to do that.

So we have witnesses today that come from a variety of areas. Mr. Scott Klara, the national energy technology of the U.S. Department of Energy.

Mr. Klara, welcome.

Mr. Jeff Muhs, executive director of the Center for Biofuels, USU Energy Laboratory at Utah State University. He'll be talking about algae fuels.

Dr. Brent Constantz, chief executive officer of Calera Corporation, will be talking about mineralization and some other issues.

And Ms. Marjorie **Tatro**, the director of fuel and water systems at Sandia National Laboratories in Albuquerque, New Mexico.

Let me thank all of you for being here. I would tell you we're going to have a hearing that's a bit shorter this morning because the Energy Department is beginning the markup of the energy bill, and I'm a member of that committee and will have to be there in a while.

But I'm really appreciative of all of you coming.

And, Mr. Klara, why don't you proceed?

And let me state that the permanent -- or the entire statements that you have will be made a part of the permanent record, and you may summarize.

Mr. Klara.

MR. KLARA: Thank you. Thank you.

Mr. Chairman and members of the subcommittee, I appreciate this opportunity to provide testimony on behalf of the U.S. Department of Energy's carbon capture and storage research, with particular emphasis today on CO2 reuse.

The department has supported research on CO2 reuse for more than a decade. When the sequestration was -- program was initiated in the mid 1990s, it was recognized that technology such as mineralization, chemical conversion to useful products, algae production, enhanced oil recovery, and enhanced coal by methane recovery could play an important role in mitigating greenhouse gases.

Although the CO2 reduction potential of these approaches is limited due to factors such as cost and market saturation of salable byproducts, these approaches are logical first entry candidates for greenhouse gas mitigation due to their ability to produce revenue from the use of CO2 to offset costs.

Enhanced oil recovery and enhanced coal by methane recovery represent attractive beneficial reuse options of CO2 that produce oil and natural gas while permanently storing the CO2 in geologic formations.

Current research activities in these areas now focus on developing reservoir management strategies to increase oil and gas production while maximizing CO2 storage, ultimately leading to best practices and protocols for using these approaches as a carbon mitigation option.

Chemical conversion methods represent another approach that can be used for CO2 reuse. CO2 can provide the carbon source for many chemical reactions that range from simply producing mineral carbonates to serving as chemical building blocks to make chemicals such as methanol and urea, and ultimately making other organic products such as plastics, composite materials and rubber, which have useful applications and represent long-term storage.

The key hurdle to these opportunities as potential CO2 mitigation approaches relates primarily to cost and volume. CO2's a stable molecule. Hence, chemical conversion to these useful end products often requires expensive processes with high temperature and high pressure that are typically not competitive with conventional methods.

Also, these potential applications are likely to utilize relatively small volumes of CO2 compared to the large volumes produced from power plants. However, even with that, chemical conversion approaches could still offer beneficial early market opportunities that provide a smoother transition to geologic sequestration.

As the senator stated, biological capture of carbon dioxide through algae cultivation is another CO2 reuse option that is gaining attention.

Algae, the fastest-growing plants on earth, can double their size as frequently as every two hours while consuming carbon dioxide. Algae can be grown in regions with desert climates so as not to compete with farmlands and forests, and they do not require fresh water to grow. They can often grow in brackish, salty water.

Algae has a desirable feature of having a considerably high oil content, with yields of oil that are orders of magnitude higher than those of traditional plant materials that could be used to produce biofuels such as ethanol and biodiesel.

While it is recognized that the greenhouse gases stored by the algae will ultimately be released to the atmosphere, there is a net carbon offset by more effectively utilizing the carbon contained in the coal.

The coal is used to produce power, and then again for algae production. Hence, a net carbon offset is realized by an increase in the energy extracted from the coal when compared to using that same coal for just power generation only.

In conclusion, advanced CCS technology will undoubtedly play a key role in mitigating CO2 emissions under potential future carbon constraint scenarios.

CO2 reuse technologies with salable byproducts are logical first entry market candidates for greenhouse gas mitigation due to their ability to produce revenue from the use of the CO2.

These options will likely provide a technology bridge and smoother transition to the deployment of large-scale geologic sequestration that ultimately will be needed to stabilize greenhouse gases.

The department's research programs are critical to ensure the availability of all these enabling technologies. I applaud the efforts of this committee and the members for taking a leadership role in these significant issues.

And this completes my statement, and I would be happy to entertain questions at the appropriate time. Thank you.

SEN. DORGAN: Mr. Klara, thank you very much.

Next we'll go to Mr. Jeff Muhs, who is with Utah State University, executive director of the center for biofuels at USU's energy laboratory.

Mr. Muhs, welcome.

MR. MUHS: Thank you, Mr. Chairman and members of the committee. It's a pleasure to speak to you today on the beneficial reuse of carbon dioxide.

I'll be summarizing findings from a report that Utah State University is jointly issuing with a number of other entities on the opportunities, challenges and research needs for algae biofuels, particularly emphasizing systems designed for carbon recycling from point-source CO2 emitters.

America faces five interdependent challenges that threaten our prosperity and quality of life: energy price spikes, climate change, depletion of natural resources, high food prices, and an addiction to foreign oil.

Although there's no single answer, algae energy systems represent a possible partial solution to all five of these challenges. Growing algae, the most productive of all photosynthetic life on earth, and converting it into fuels could help mitigate carbon emissions, reduce oil imports and price shocks, reclaim wastewater, and lower food prices.

Fundamentally, algae use solar energy and nutrients to transform CO2 into organic matter. Due to their simple biological structure, they capture carbon more rapidly than terrestrial plants and store it in a form that could be processed into fuels such as biodiesel.

Some algae strains are capable of doubling their mass several times a day and, unlike terrestrial plants, algae can be cultivated on marginal desert land and using saline, brackish or wastewater.

Since some species have a high affinity for CO2, citing these algae systems near point source CO2 emitters is a very attractive option. Research has demonstrated that the yields can be dramatically improved by enhanced concentrations of CO2.

Because of its high lipid or oil content and growth rate, algae can produce between 10 and 50 times more biodiesel per acre than, for example, soybeans.

To compare the two feed stocks, if all the soybeans harvested in the U.S. were converted into biodiesel, the resultant fuel supply would accommodate less than 10 percent of our annual diesel fuel needs.

Conversely, if an area roughly the size of one-tenth of North Dakota or Utah were to be converted into algae systems, it could provide all of our diesel fuel needs. So because of that enhanced yield opportunity, there's a big opportunity.

The fundamentals of algae energy systems are sound. As a recent article in National Geographic noted, "There's no magic bullet fuel crop that can solve our energy woes without harming the environment, says virtually every scientist studying the issue, but most say that algae comes closer than any other plant."

But many challenges lie ahead. And our analysis indicates that the overall life cycle cost of algae energy systems must be reduced by at least a factor of two and probably much more. Unlike traditional crops, the technology needed to grow and harvest algae using industrial or agricultural processes is still pre-commercial.

In the field of plant biology, algae's one of the least-explored fields. Recycling carbon is a new concept, and there are challenges related to separating, compressing and delivering CO2 into these algae cultivation systems.

To cultivate algae in open ponds, land and water, which must be replenished because of evaporative losses, are required. Energy's needed to keep the algae stable, healthy and growing. Invasive species can -- which can kill algae must be controlled.

In enclosed growth systems, capital costs for equipment used to enclose, mix and maintain cultures must be reduced. In both scenarios, surface shading limits the amount of sunlight that can be used constructively to produce biomass.

After cultivation, algae must be de-watered and dried prior to oil extraction and fuel production. In each step along the way, energy and other resources are required.

But by harnessing the same biology, chemistry and genetics that led to the doubling of yields in traditional crops, we should be able to do the same with algae.

And advances in optics, mechanical engineering and other disciplines are leading to scalable cultivation systems that better utilize sunlight and have the potential to meet cost targets.

Indeed, algae has a unique potential to produce renewable fuels and recycle carbon sustainably without interfering with food supplies. To succeed, however, private and public cooperation is critical. Without it, the algae industry will struggle to reduce cost and integrate subsystems.

Without regulations limiting carbon emissions, utilities -- and in particular, small CO2 emitters -- will have little motivation to explore the reuse options.

Therefore, a robust and well-integrated RD&D program will only occur with government involvement both in sponsorship of research and development and enactment of policies in future energy and climate change legislation that help to accelerate commercial deployment.

We recommend that Congress authorize and appropriate funds for an algae-related RD&D program at the Department of Energy. It should include research on life cycle analysis, leverage strengths of existing department programs, and be coordinated at a systems level.

It should take advantage of new program management tools and include a portfolio of activities from foundational research to integrated demonstration.

And deployment projects should be -- should demonstrate the viability of technologies at a scale large enough to overcome infrastructure challenges and include regional partnerships similar to the department's programs in geologic sequestration.

Thank you very much.

SEN. DORGAN: Mr. Muhs, thank you very much. We appreciate your testimony.

Next we're going to hear from Dr. Brent Constantz, chief executive officer and founder of Calero -- Calera, I should say, and, from his biography, specializes in high performance and novel cements. Is that the case, Mr. Constantz?

MR. CONSTANTZ: Mm-hmm. (In agreement.)

SEN. DORGAN: And is the inventor on over 60 issued U.S. patents on the subject.

You may proceed. Thank you for being with us.

MR. CONSTANTZ: Thanks.

We really admire the Senate's vision in appreciating the beneficial reuse of CO2 and turning it into a profit center for a CO2 emitter instead of a huge liability for them.

Just looking at the mass balance of carbon on earth, if we look at the Kyoto Protocol, we're calling for 5 billion tons of mitigation. And to put that in perspective, power plants and cement plants put out about 11 billion tons of CO2 a year into the earth's atmosphere.

We could put 16 billion tons of CO2 a year into cement in aggregate. So we could more than triple the Kyoto requirement putting CO2 into cement in aggregate.

Calera's developed breakthrough technology that allows us to handle dilute flue gas streams such as from coal, which are only about 15 percent CO2, which is a major challenge otherwise. It needs to be separated via very expensive techniques.

It can also be taken from natural gas in cement plants, which are also dilute streams of CO2, unlike what's been used in EOR.

This technology also has multi-pollutant control features, especially with SO2 and NO as well as mercury and other toxics. The absorption technology is an absolute breakthrough and has allowed us to have very high absorption of the raw flue gas with no separation step.

We have developed a revolutionary low-voltage base technology which allows us to produce base at one-fifth the voltage of traditional base generation and have accelerated mineral dissolution technologies to produce. Then we utilize the waste heat from the power plant to dry the powders to make cement.

Our chief operating officer joined us from NRG, the largest non- regulated power company, where he held the same role. Our head of emissions came from 30 years' experience with General Electric. His Ph.D. was on the burning of coal. Our head of process technology came from Exxon, where he spent 20 years building their process plants.

We're producing green building materials. Our first product, which we launched already, is a replacement for Portland cement, a supplementary cementitious material. It's been tested against ASTM C 1157, and we have a 15,000-square-foot lab where we do concrete and cement testing.

It was launched at the World of Concrete, which is an 80,000- person convention. It's been well addressed by the entire Portland cement industry and the ready-mix industry, as well as the asphalt industry.

In addition, we're producing aggregate. I have an example of the aggregate. At Stanford I teach carbonate sedimentology, and if I were to put this piece of aggregate on my final exam -- and let's say on a microscope -- none of the students could tell you that this wasn't natural limestone, which is what two-thirds of all natural aggregates are.

These mixed designs are carbon negative, so they're not just carbon neutral, but we're actually sequestering CO2 from the power plant into the solid material. And we can sequester, as I said, 16 billion tons of CO2 a year this way on an ongoing basis for centuries to come. This is a profitable option both for a cement plant that has to deal with their CO2 as well as a coal plant.

The aggregates provide the possibility of specialty products such as lightweight aggregates which are very important and sell or aggregates for pervious concrete.

One byproduct of our process is fresher water, because we take all of the hardness out of the water to combine with the carbonate. And this fresher water can be desalinated, via reverse osmosis, for less than 50 percent the regular energy intensivity.

So the water aspect of the profit is important. In fact, in Moss Landing, where we have a 200-acre pilot plant, we already have a contract with the local water district to produce fresh water in addition to everything else we're producing.

Other revenue sources are the carbon tipping fees and allocations, where we're working in Victoria, Australia already, doing this. We have the ability to use off-peak electricity consumption, so this can be done with almost no energy footprint.

And the important point I'd like to point out is this is the permanent removal of CO2. It's not temporary. We convert the CO2 to carbonate, just like the white cliffs of Dover. It's going to stay there for millions of years. It's never coming back.

I'd like to urge the Senate to consider to level the playing field, because there's currently a monomaniacal focus on geologic sequestration in all of the language.

We believe a more inclusive approach to look at all the ways of dealing with carbon would be better for everybody, and focus on the outcome of sequestering CO2 as opposed to one specific method, which is geologic sequestration.

And I think the U.S. needs to provide international leadership in this area, showing the broad variety of solutions for removal of CO2.

Thank you.

SEN. DORGAN: Dr. Constantz, thank you very much.

And finally, we will hear from Ms. **Tatro**, and she is with the -- Marjorie or Margie, I guess. Marjorie -- Margie **Tatro** is the director of fuel and water systems at the Sandia National Laboratories.

So, Ms. **Tatro**, thank you for being with us. You may proceed.

MS. **TATRO**: Great.

Thank you, Mr. Chairman, Senator Bennett and distinguished members of the subcommittee.

As you know, we are faced as a nation with two challenges that actually inspire us as well to think about the reuse of carbon dioxide not only to enable this use of the coal reserves that we have, but we believe that carbon dioxide as a fabulous feedstock for creating liquid fuels that could be inserted into our existing infrastructure is really a fabulous and innovative idea.

You mentioned algae-based biofuels, which do have tremendous promise, and we agree that those need to be developed in a way that allow us to scale them up to the kind of quantities to make them commercially and technically viable.

And I wanted to talk to you about another technology today that offers some of the same benefits. We've done a little work at Sandia National Laboratories in taking concentrated sunlight, high- temperature solar energy, and putting it into a heat engine.

This heat engine takes carbon dioxide in one side, takes water in the other side, and splits those molecules apart to then thermo-chemically recombining those together to create a liquid fuel -- in this case, it's methanol. And there are commercial processes that can convert methanol into gasoline, jet fuel and diesel.

This is another way to use carbon dioxide as a feedstock. Just like it's a nutrient for algae, it is a feedstock for a liquid fuel that can be compatible with our existing transportation infrastructure.

Another area I wanted to mention that we ultimately have to look at is being able to extract carbon dioxide from the air, because if we are going to have progress in reducing the overall emissions from our energy enterprises into the atmosphere, it's important that we think about scalable, affordable technologies that can capture that CO2 ultimately from the air and reintroduce it or recycle it into some of these fuel feedstock options.

I agree that our first steps are using carbon dioxide from our coal enterprise as a fabulous feedstock for these transportation fuels, and ultimately we need to make progress in pulling carbon dioxide from the atmosphere as well.

These are just a few ideas that are out there. We believe that this nation is ready to step up to this innovative area of recycling and reuse of carbon dioxide. And I believe there are many ideas out there that none of us have even thought of, and it's worth an investment by this country to stimulate those ideas and bring them forward.

I think the U.S. has a chance to be a leader in these areas.

But right now let me tell you, other countries are also investing in these areas and my fear is not only that we might be left behind in this area, but perhaps we could end up importing both these technologies or the fuel they create from foreign sources, which would not help our energy security situation.

So we've talked about algae. We've talked about synthetic fuels that could come from renewable sources like solar energy. We've talked about the idea of extracting CO2 from the air. And there are many more details in my written testimony that I believe you've been provided.

But we're excited. We think this is a great innovative area for the country. We appreciate and applaud the subcommittee's leadership in looking at this area, and we stand ready to support this area with innovation from a number of different collaborative teams all across the country.

With that, I'd like to conclude and look forward to your questions.

SEN. DORGAN: Ms. **Tatro**, thank you very much.

The first question for all of you is we are working on this issue of carbon capture, and most people say carbon capture and sequestration -- CCS, they call it.

And the sequestration side of it really describes a mind-set. Here's what we have to do: We have to figure out a way to grab the carbon, separate it and put it someplace deep underground forever. I mean, that's kind of the mind-set of what CCS means.

The purpose of this hearing is to say, "I think there's another mind-set out there that I'm much more interested in," not that I'm not interested in sequestration.

I'm much more interested in finding: Is there a way to take this carbon and provide from it beneficial use, which might well allow us to cap carbon emissions and actually have very little cost, if you could find the right kind of beneficial use.

So the question for all of you is as you watch the federal government invest in all these things, do you consider there is largely a bias in favor of sequestration or in geologic issues as opposed to other alternatives? Because, Ms. **Tatro**, you just suggested that, you know, we're sort of moving along here but other countries are moving perhaps in some cases faster.

Is there a circumstance where you have more difficulty in this whole collegiate discussion about carbon capture with your approach as opposed to sequestration?

Ms. **Tatro**?

MS. **TATRO**: Well, I believe there is a lot of activity being looked at now for carbon capture and sequestration. And it is a step forward we need to take. I don't believe that the country has organized around this idea of recycling carbon dioxide.

There has been no organized, concerted effort to bring innovation ideas to the table beyond the capture and sequestration. But I think the science and technology and innovation community and the industry and universities have ideas in their mind and have talked about them.

There's just no concentrated way for those ideas to come forward at this point.

SEN. DORGAN: But with the new secretary of energy coming from a science lab, one would think that this is the time.

So tell me, Mr. Muhs, what do you think of Dr. Constantz' testimony? You're working on a range of things at Utah, but you heard Dr. Constantz testify on something I thought is very novel and unique.

MR. MUHS: My assessment is there's no silver bullet, and that we should look at biologic approaches as well as chemical approaches to sort of, in his case, reuse for the use of cementitious materials.

So in my mind, we have to look at all of those things. And sort of to follow on with what Ms. **Tatro** said, I think the whole idea of recycling is a mind-set, and it's one that sort of requires a certain level of osmosis into one's mind.

Obviously, when you think about recycling in a very general sense, the European countries have done a lot on that in the past in just in general sense -- things like recycling aluminum and things of that nature.

So I believe that it takes a little time, but I do think we're to that point, and I think you're right.

SEN. DORGAN: Mr. Klara, my understanding about algae is that some strains of algae -- there are many, many, many different strains of algae.

MR. KLARA: Right.

SEN. DORGAN: And so some would be very productive with respect to this and some not. Tell me how we go about identifying which would be the productive candidates.

MR. KLARA: Well, absolutely, that's a correct statement. And a lot of the algae work that's ongoing right now is looking at literally dozens and dozens of different strains to find the most robust strain that could have the optimum performance under flue gas conditions where they're getting the CO_2.

And there are also a lot of nifty approaches coming forward with algae as well. One of the issues you have is there's so much algae produced, you have to cultivate and remove it to keep the algae growing, and so there's all kind of schemes being looked at right now to try to get past that issue so that you can have a truly continuous process.

SEN. DORGAN: Where do you think is the most successful work going on in algae at the moment on a trial basis? I'm talking about growing algae and then harvesting the diesel fuel and so on.

MR. KLARA: Well, I think by far, relative to using carbon dioxide from an energy facility in a coal plant, Arizona Public Services is showing themselves to be a true leader in this area.

SEN. DORGAN: Yeah, and I've been out to take a look at that. I mean, we need to do a lot of everything to find out what works and what scales up.

MR. KLARA: Right.

SEN. DORGAN: But, Dr. Constantz, now, let me -- yours sounds like a silver bullet. But, you know -- and you can take the carbon and, with your process, turn it into concrete. And you've captured all of the carbon. It probably has a significant value. You're talking about how much you could produce worldwide and so on.

What -- when will you be able to scale up your process so we understand does this work at scale? Is this -- Mr. Muhs says there is no silver bullet. But is yours close to a silver bullet?

MR. CONSTANTZ: Where we're at is we have a 200-acre facility next to a 1,000-megawatt power plant in Moss Landing, California.

We also have a coal-fired boiler simulator there, so we're burning both coal and gas. And we're making cement every day. In a batch process, we've been making five tons a day for several months.

We have just commissioned a plant which is a continuous process, which runs 24/7 solely on coal, which is producing one ton a day.

The large EPC firms working with us say the parameters that they're getting from this continuous plant will allow them to design and construct a plant of any size.

SEN. DORGAN: And you think this approach is going to demonstrate at scale your capability?

MR. CONSTANTZ: Yeah. I mean, I think we're doing that right now. And all the --

SEN. DORGAN: Well, if the --

MR. CONSTANTZ: -- energy balances look very good.

SEN. DORGAN: Don't mean to interrupt you, but if you're doing it right now, and it was demonstrated at scale that you can produce a product of substantial value and sequester virtually all of the CO2 at the same time, it seems to me there'd be a traffic jam leading right to your office of everybody in the world that says, "You know what? You found a silver bullet. We need to do that."

MR. CONSTANTZ: Well, in fact, you know, the materials I'm pointing out to you are -- are highly sought after by the entire construction industry and we're -- they are beating a path to our door.

I mean, we're talking to every major producer of Portland cement and aggregate in the world. And you know, we're talking about the whole fabric of the infrastructure here. It's not just a power problem.

You know, if you're a hammer, every looks like a nail, and just what you said, the goal is not to purify CO2 so you can inject it into the ground. The goal is to lower the amount of carbon in the atmosphere.

And you need to understand the whole construction industry has a huge problem, too. You know, the cement industry, for every ton of cement produced, produces a ton of CO2. They're under the same problem that the power guys are under.

And so they're looking for ways to mitigate their CO2, and they see the opportunity to turn this liability into a profit. You know, 60 percent of the aggregate used in northern California is imported from British Columbia on barges, and it's all limestone. It looks just like this.

We can produce it locally with the carbon. We're producing it in a profitable way. And it links in with the water. You know, at our plant in Monterey we have a contract with the local water district because they have big problems, and we can lower the energy intensivity of their reverse osmosis by 50 percent.

So we're actually doing it.

SEN. DORGAN: Ms. **Tatro**, what do you think of Dr. -- I mean, you're looking at a lot of different things. Give me your assessment of Dr. Constantz' presentation.

MS. **TATRO**: Yes, I think there is tremendous merit to taking CO2 and permanently sequestering it in these construction materials. I think that's a fabulous idea. I think it could be complemented nicely by using CO2 to create liquid transportation fuels.

This is my point, though, in my testimony. I think there are a lot of good ideas out there that have not come to the forefront because there has not been an organized effort to call for these ideas. I think it's a fabulous idea. It would complement making transportation fuels very nicely.

SEN. DORGAN: Now, you've worked since 1985 for Sandia, and you've got a couple hundred people working with you. You lead a couple hundred people working on these issues. So you've spent a lot of time and a lot of public funding working on these issues.

Do you think 10 years -- let's fast-forward five and 10 years.

MS. **TATRO**: Okay.

SEN. DORGAN: And let's say that we really begin to focus on all the aspects of carbon capture and also start to emphasize beneficial use.

Do you think in five to 10 years we'd make significant progress on the beneficial use side?

MS. **TATRO**: I believe we can. I think the 10-year time frame, to answer your question earlier about when the maturity of these technologies is going to vary. But a 10-year time frame is a very reasonable time frame for a target of doing some of these concepts in a way that's both affordable and technologically feasible.

I will offer this one caution. Those who are expert in this area of policy, such as yourselves, ought to be looking at the current policies that are being discussed to make sure they do not disincentives the recycling of carbon dioxide as an option. That will significantly affect the time frame in which these technologies can be viable.

SEN. DORGAN: Well, this committee's going to try to have an impact on that. And we tried to have an impact on that in the stimulus bill as well, to make sure that there's -- most of these things tend to move towards the geologic side of things, because of CCS. So we intend to try to have a significant impact on that.

Senator Bennett?

SEN. ROBERT BENNETT (R-UT): Thank you very much, Mr. Chairman. And thank you for the hearing.

Thank you to all the witnesses.

And a special welcome to my fellow alumnus from Utah State University. I became a graduate as of last Saturday. They gave me an honorary degree. (Laughter.)

SEN. DORGAN: How were your grades?

SEN. BENNETT: I -- what's the -- you pencil-whipped them through?

I would ask that the algae report be part of the record, if that's not been done already.

SEN. DORGAN: Without objection.

SEN. BENNETT: Ms. **Tatro**, I think you hit on it exactly, and words have meaning sometimes that seem innocuous enough, but we have as a government, as a people, we have come to regard CO2 as a pollutant. And your testimony here collectively says CO2 is a resource.

And if you simply make that semantic change in defining it, the whole world changes. So I intend to start talking in those terms. And I would -- I gather you would be willing to start talking in those terms. And that can be the shift in mind-set that can get us in the right direction.

Now, Mr. Klara, will the DOE start thinking, okay, how do we organize to take advantage of this resource to generate new energy? Wouldn't that be a significant mind shift at DOE?

MR. KLARA: Well, absolutely. But I'm not sure that a mind shift is quite needed. We have been investing around $35 million, for example, in fiscal year '09 in reuse-related concepts.

As the senator -- Senator Dorgan has stated, we're looking at a very aggressive influx of funding, potentially, out of the stimulus funding to this area as well.

I would also caution, though, also with the approach to having no silver bullet that to stabilizing emissions. That at the end of the day, all the analysis continue to show that the emissions are just so large that CCS will likely have to be the backstop.

SEN. BENNETT: I realize that, but I am encouraged by what you just said -- the backstop.

MR. KLARA: Right.

SEN. BENNETT: If we think of it as a resource, and how can we use this resource -- oh, there's still some left over that we have to deal with, all right, we'll use sequestration as -- at the back end rather than the focus which is there now, which is that everything -- it is a pollutant, everything we can do to get rid of it is where we ought to be going.

And the testimony here is, no, it's a resource. Now, it may be a resource in overabundance, so that that that's left over becomes a nuisance, but that significant mind shift I think has to take place.

And I realize in the stovepiping of the way we organize our government, you're focusing entirely on energy. So you can't even talk to Dr. Constantz, because he's not producing energy. He's producing concrete.

Let's kind of break down those sorts of stovepipes. Realize, again, this is a resource. And it's a resource that can be used to turn into something very valuable.

Now, Dr. Constantz, how competitive are you with Portland cement? Without a government subsidy, just doing what you're doing, can you under price traditional Portland cement in the market today?

MR. CONSTANTZ: Yeah -- well, there's two components. There's the cement and the aggregate --

SEN. BENNETT: Right.

MR. CONSTANTZ: -- which compose concrete. And both of them, in our case -- half a ton of the material sequesters half a ton of CO2 within it. Our price to the gate is competitive with the price to the gate of Portland cement.

It's much more competitive, though, if you consider the future, because, remember, the cement guys are under the same constraints the power guys are under. So they have to put emissions controls in place like in California, we have A.B. 32, and that's going to drive their cost to the gate up to about $90 a ton, and we'll beat that big time.

SEN. BENNETT: I understand that, and that's a political decision rather than an economic decision. I'm not saying it's the wrong decision. But it's a political decision to put that extra cost onto traditional Portland cement.

And the point I want to discover is even without that extra cost on them, can you compete today?

MR. CONSTANTZ: On the cement side, we can easily compete and it's very profitable. On the aggregate side -- aggregate's not a very high-value product. It sells for 10 to $20 a ton. So there, by having a carbon credit or like in Australia, we have allocations that we get, that can be very profitable.

However, as I mentioned, other specialty products, like lightweight aggregate, sell for as much as $60-$70 a ton, or the angular aggregate for pervious concrete, which is used everywhere today, or elongated -- see, we can make them any shape we want.

SEN. BENNETT: Sure.

MR. CONSTANTZ: So there are a number of high-value products. The aggregate is easier to get on the market. That's tested with fewer tests than the cement. But we're in testing for both of them.

Our vice president of materials research is the past president of the American Concrete Institute, and he chairs the five -- ACI 518 committee that oversees all the other testing committees. So we're very much in contact with that.

And the cement industry is really thrilled about this, because just by, for example, substituting the sand in their mix design with our sand, they can bring a yard of concrete, which is normally 500 pounds of CO2 net emitted, down to carbon neutral.

If they supplant both the sand and the gravel in the concrete, plus only replace 20 percent of the Portland cement with our cement, they can bring it to a negative 1,100 pounds per yard of sequestered CO2.

So we're negotiating with many, many power plants, but we're also negotiating with many, many cement plants. And at a cement plant, an average cement plant produces a million tons of cement a year. So that's 2 million tons of our product that we can produce.

And because transportation is a large amount of the cost in delivering concrete, which is the commercial product, by having the aggregate produced locally right at the cement plant from their emissions, and being able to take that out along with their cement to the ready-mix plant is an incredible win for everyone in the Portland cement industry.

SEN. BENNETT: Okay. Will you furnish for the record some national figures so that if everybody who is in the cement and aggregate business shifted over, what the national amount of sequestration would be.

MR. CONSTANTZ: Sure. So in the United States, we use about 124 million tons of Portland cement a year. And that goes into about roughly 600 million tons of concrete, okay? So from that 124 million tons of Portland cement, we're producing 124 million tons of CO2.

The larger aspect of it is in the United States, we use 3 billion tons of aggregate a year. And approximately 500 million of those tons go into concrete. The other two- and-a-half billion tons go into asphalt and road base.

SEN. BENNETT: And all of that would include sequestered CO2?

MR. CONSTANTZ: All 300 million tons. And limestone is the preferred aggregate, because it's stable at high pH, and concrete, as you know, has a pH of 14.

SEN. BENNETT: Sure. Okay. That's the kind of scale that I was looking for.

Mr. Muhs, you listened to Ms. **Tatro**. Can you two make music together? Can you make fuel?

MR. MUHS: Well, I think so. There's -- in both cases, we're using solar energy, ultimately. And there's different uses for solar, and biological systems, obviously, require sunlight.

One of the things that we've done at Utah State to try to help the scalability of algae, for example, is improve the volumetric growth of algae -- that is, how much algae can grow in a volume of aqueous or water solution.

Also, looking at using saline water from the Great Salt Lake. And we found some strains of algae that had a lot of oil and grow very fast there.

So I think, to follow on that question, yes, we can. And one of the things that we're doing to try to embed better solar energy use is look at ways to increase the amount of sunlight we can get into these algae systems.

You've seen some of these vertical reactors and things of that nature that Senator Dorgan had mentioned. By using sunlight more constructively, we can reduce surface shading and increase the volumetric growth by maybe a factor of 10.

If we do that, then we use 10 -- you know, 10 times less water. And in doing that, we have a whole lot less energy moving energy around, or moving water around, and it makes algae more scalable.

We think that -- our industry colleagues who helped write our report say five years. Some of the academic folks say 10 years to sort of commercial viability, economically. Maybe there's -- somewhere in between those two points is where the real number lies.

SEN. BENNETT: Mr. Chairman, thank you for your indulgence for this. I've been told, growing up there, that the Great Salt Lake is only good for two things: salt and sunsets.

And if, indeed, we can use the brackish water that's there to create energy, that is enormous, because one of the primary challenges with respect to corn ethanol is the enormous amount of water that it uses, and water is the new oil, looking ahead.

The water resources are going to be as scarce as the oil resources around the world. And to be able to use this kind of thing with brackish water -- this is a very exciting prospect. And I again, thank you and congratulate you for convening the hearing.

SEN. DORGAN: Senator Bennett, thank you very much.

Senator Tester.

SEN. TESTER: Yeah. Thank you, Mr. Chairman.

I'm going to stay with Dr. Constantz for a second.

During your answers with Senator Bennett, you had said that the price, without subsidies, was competitive. And then I drifted for a second, and then we were talking about not being competitive.

It's competitive on the concrete and not competitive on the aggregate, is that what it was?

MR. CONSTANTZ: Right. So you know, concrete has both cement and aggregate in it to make the concrete, and the price to the gate -- the national average in the U.S. is about $30. Most of the cost in a delivered yard of concrete, though, isn't in that. It's in the transportation.

SEN. TESTER: Transportation.

MR. CONSTANTZ: For aggregate, on a national average, it would be sort of -- $10 to $20 a ton would be the retail price. For cement, the average price varies around $100 to $110. So the Portland cement replacement component is extremely profitable.

Now, on the aggregate --

SEN. TESTER: Got you.

MR. CONSTANTZ: -- the specialty aggregates, like the lightweight aggregates --

SEN. TESTER: It can work.

MR. CONSTANTZ: ... can be $70 a ton.

SEN. TESTER: Okay. And did you say in your testimony that you did not have to separate the CO2 flow?

MR. CONSTANTZ: Yes. I think that's the principal distinction -- you know, if you have a coal plant and you want to get into chilled ammonia or MEA, you also have to scrub all your SO2.

SEN. TESTER: Yeah.

MR. CONSTANTZ: And even if you're currently compliant with SO2, it's not to the level you would need it to be to then put an MEA unit on the end. So if you own a coal plant and you want to do MEA or chilled ammonia, you have to upgrade your sulfur control --

SEN. TESTER: Right, so --

MR. CONSTANTZ: -- and take on more parasitic load and then put on the other -- we take raw flue gas and we have greater than 70 percent absorption.

SEN. TESTER: Okay. You have 70 percent absorption from the CO2 and the NOx and the SOx are not an issue because they're automatically absorbed, too?

MR. CONSTANTZ: Right now, we know we're taking all the SO2. And we're investigating the NO conversion to NO2 and the mercury, arsenic, lead, selenium as well.

SEN. TESTER: Okay. So the jury's still out on those, but you're --

MR. CONSTANTZ: For sure the SO2, yeah --

SEN. TESTER: Okay. All right.

MR. CONSTANTZ: -- as well as the CO2. My V.P. of emission control has 15 already. It's something we're pretty knowledgeable about.

SEN. TESTER: Yeah. You're -- you said you're making five tons of cement a day.

MR. CONSTANTZ: In a batch process.

SEN. TESTER: In a batch process.

MR. CONSTANTZ: But we have a continuous pilot plan up and running now, which is running 24/7 just putting out a ton a day. And that plan is allowing us to look at the key process indicators --

SEN. TESTER: Okay. So --

MR. CONSTANTZ: -- which are needed to define a plan of any scale, according to the EPC contractors.

SEN. TESTER: So what's the inhibitor of Coal Strip, Montana with their four coal-fired generators starting up a cement plant in Coal Strip, Montana? What's stopping that?

MR. CONSTANTZ: Actually, you know, that -- we've been -- have a lot of support. You know, we put a grant together for a coal plant, and we went out to the local ready-mix suppliers, and they all wrote very laudatory letters of support, saying, "If you make it, we'll sell it."

SEN. TESTER: Oh, for sure.

MR. CONSTANTZ: You know, and so just -- you know, you have to have a local cement market -- but even if you don't have a local cement market, they -- you know, they're putting in asphalt roads.

SEN. TESTER: Yeah.

MR. CONSTANTZ: There's road base. There's plenty of uses almost anywhere. And the fact is that the electrical power plants and the cement plants are always in the same place, because they're where the people are, and they're both things that are hard to transport.

SEN. TESTER: Yeah. So what's stopping it?

MR. CONSTANTZ: Well, we're going as fast as we can.

SEN. TESTER: Is it because there's not a price on CO2 that's stopping it? Or what's stopping it? Because if you can make money making cement out of CO2, eliminate and not have to separate all the scrubbing and all that stuff, just use your flue gas, what is inhibiting this from happening?

Because it looks to me like if I had -- if I was on a board of directors, I'd say, "Do this. Do it tomorrow." And we just eliminated one big old headache.

MR. CONSTANTZ: Well, that's what my board's telling me. You know, I mean --

SEN. TESTER: So there is nothing inhibiting it other than a lack of knowledge.

MR. CONSTANTZ: I'm giving one of the addresses at the National Coal Council next Friday --

SEN. TESTER: Okay, good.

MR. CONSTANTZ: -- And I'll have a much more extensive discussion --

SEN. DORGAN: Can I just --

SEN. TESTER: Yeah, go ahead.

SEN. DORGAN: If I might just interrupt, my staff has indicated there still is remaining life cycle testing for CO2 life cycle balance. Is that correct -- in this process?

MR. CONSTANTZ: Actually, you know, my -- one of my specialties is isotope geochemistry. And we have a whole team of -- we have 18 Ph.D.s in the company. One of them is just using Carbon-13 analyses.

So this will be the most -- these are the most sophisticated lifecycle analyses ever done on any carbon technology. And we're following -- we can tell an atom of carbon from coal versus water versus the atmosphere and where it goes in these analyses.

SEN. DORGAN: And then the tactical testing to meet the industry standards -- are you there?

MR. CONSTANTZ: Well, that's what we presented back in February at the World of Concrete --

SEN. DORGAN: And have they been accepted?

MR. CONSTANTZ: -- the ASTM testing. Every -- the way it works is every state has their own Department of Transportation.

SEN. DORGAN: I see.

MR. CONSTANTZ: So in California, we have Caltrans. Caltrans has a lab in Sacramento. You send them your product. They do their own testing. Every state's different. And that takes them about 18 months to do that testing on concrete.

SEN. TESTER: Okay. Thank you, Mr. -- and I want to move on.

And, by the way, I think that how we deal with our carbon is just how we deal with our energy policy. It has to be multifaceted, very diverse, and so I think there's room for everybody in this equation.

But it does intrigue me that you're this far along with this technology. And I've heard of it, but I certainly didn't think it was this far along, which is good news.

I want to talk a little bit about algae for a second.

Is all your work been in closed -- Mr. Muhs -- all your work -- or Mr. Klara -- all the work been done in closed systems, or is there some work that's being done out in the open?

MR. MUHS: A of working being done in open systems. They're easier to build. They are easier to operate.

SEN. TESTER: Are they limited to the southern part of the U.S., or can they be done all over?

MR. MUHS: They are not limited to the southern part of the United States. Matter of fact, issue of water supply is such that it may be just as viable up north in some cases. One limiting factor may be temperature in some cases, in northern regions.

SEN. TESTER: And in the end, have you done any analysis on -- once it gets right down to it, because you're making diesel fuel out of the algae, how many gallons of water it takes to make a gallon of diesel fuel, which is a big discussion about coal to liquids?

MR. MUHS: In the enclosed systems, it's very minimal, because you're essentially recycling most all the water.

SEN. TESTER: Okay.

MR. MUHS: In the open systems, it's much higher. And I looked at an analysis yesterday from Sandia and Los Alamos on water use and algae, and I still don't have any -- a number from them yet in terms of actual -- in open systems.

SEN. TESTER: I Would love to get that, although I would imagine a lot of it depends upon sunshine.

MR. MUHS: Exactly, where you're at.

SEN. TESTER: Yeah.

MR. MUHS: For example, arid climates are going to have a whole lot more evaporative losses than up north.

SEN. TESTER: Exactly. And then I'm just going to make the assumption that when you use wastewater it improves the quality of the wastewater --

MR. MUHS: That's correct.

SEN. TESTER: -- Because it removes the nutrient load?

MR. MUHS: It removes the nutrients. For example, in Logan, Utah, we have a huge wastewater facility, and we're already working towards that.

SEN. TESTER: Is lack of nutrient load an issue when you're not using wastewater?

MR. MUHS: It can be. It can be, because obviously you need the same nutrients that regular farm crops need. And so issues in the algae -- one of the main ones is proximity to nutrients as well as proximity to CO_2 -- enhanced CO_2.

SEN. TESTER: Has anybody done any analysis about the amount of -- if we were to maximize this to also -- do we have plenty of wastewater to fill the need in the country?

MR. MUHS: That's a good question. I don't have an answer to that. My estimate would be that we do have an excess supply of wastewater right now, and that it would take quite a long time for us to get through that before we needed --

SEN. TESTER: All right. All right. I would tend to agree with that.

Ms. **Tatro**, you talked about disincentives in policies that we may put forward or potentially appropriations.

Could you give any examples of that that exist now that there's a disincentive to any one of these industries or potential industries that we have done?

MS. **TATRO**: So myself and my organization are not policy experts, so let me just caveat this response.

SEN. TESTER: No problem. Neither am I. (Laughter.)

MS. **TATRO**: And I can't cite a particular policy that's disincentivized recycling. And I don't know what all the conversations are in Washington about various ways to either put a price on carbon or to limit the -- you know, the cap and trade.

All of those policies have implications for recycling, and I don't know. I just think that needs to be part of the conversation in the formulation.

SEN. TESTER: I agree. I just need to make sure that we don't have unintended disincentives in some policy we make, so if you see that coming down the pipe, I'd love to hear about it, because truthfully, I think that it needs to be a multifaceted arrangement that we deal with CO_2, and I don't want to disincentive anybody if they've got a good idea, which brings me to my next question.

You had talked about the fact that we haven't really called for these new ideas. Is that the same case since Dr. Chu is in the DOE, or is there things we can do that really can help excite people to step up to the plate?

MS. **TATRO**: Absolutely. I'm really excited by Dr. Chu's direction and the support I think he also has from Congress in creating these collaborative energy Grand Challenge Centers that may be focused on some of these problems. That's a fabulous way to get cross- organizational teams working on some of these problems. I'm very excited.

I think he sees the benefit of getting coordinated teams across different parts of the Department of Energy and with different federal agencies to motivate people to work on these problems. I'm very excited by what I see. I think it will help tremendously.

And I know we appreciate the support from Congress that he's receiving for that.

SEN. TESTER: Okay. Just a couple more and then I'm done.

Mr. Muhs, you talked about one-tenth the area of a state like Utah or North Dakota could be used to fill all our diesel needs. Is that in a closed loop, open loop, or does it matter?

MR. MUHS: That was based on something in between, essentially, in terms of --

SEN. TESTER: Little bit of each?

MR. MUHS: Yeah. Yeah. It essentially took values for production that were lower than enclosed but higher than open systems to make that calculation.

SEN. TESTER: All right.

The other thing you -- Ms. **Tatro**, you talked about a heat engine that could make methane out of CO_2 and water and sunlight and heat. I'll ask you the same question I asked Mr. Muhs.

What's the water use in making the methane? Is it one to one or less than that or more than that?

MS. **TATRO**: So the product that is produced is methanol, which is a liquid --

SEN. TESTER: Yeah, methanol.

MS. **TATRO**: -- material --

SEN. TESTER: I'm sorry.

MS. **TATRO**: That's all right. And the question is still valid. And I don't know the number off the top of my head. The amount of water that's used compared to the amount of CO2 fuel? Let me get back with you on that.

SEN. TESTER: That would be great. I'd just --

MS. **TATRO**: I just don't know it off the top of my head.

SEN. TESTER: I'd just love to know it.

And that's probably about it. I want to thank you all for your testimony. I think that you've all thought outside the box.

Mr. Constantz, do you see CO2 as an asset at this point in time? You can make money off CO2.

MR. CONSTANTZ: Yeah, in many ways, from -- from aggregate, from cement, from fresh water. And if there's further carbon monetization from the CO2 emitter, we believe it can be a very profitable --

SEN. TESTER: I like what I hear.

MR. CONSTANTZ: -- and job-creating enterprise.

SEN. TESTER: Mr. Klara, my apologies. I didn't ask you any questions. Next time.

MR. KLARA: No problem, sir.

SEN. TESTER: Thank you.

Thank you very much.

SEN. DORGAN: My colleague, Senator Tester, just talked about thinking outside the box, and Senator Bennett talked about stovepipes. In many ways, it's kind of the same discussion.

We do in our government, I think, push a lot of money towards research and so on, but a lot of it's done in a stovepipe. I think -- so I think when we try to address this larger issue of climate change and carbon capture and so on, we really do need to think outside the box.

I was just thinking, as Senator Tester was asking questions, about Dr. Venter -- Dr. Craig Venter, who came to see me a while back. And I think he has -- this is probably such a simpleton layman's description -- but he's got scientists, I think a couple hundred scientists, working on the prospect of perhaps creating synthetic microbes that would consume coal and in that consumption produce methane.

And you know, so that's thinking outside the box, right? Perhaps doing it in situ. I have no idea about the carbon issue there, but I'm assuming consuming coal underground with synthetic microbes and turning coal into methane probably also is an outside-the-box approach to deal with the carbon issue.

But the reason that I wanted to have this hearing is that I want us to begin thinking differently about this issue and this challenge. We do have issues in front of us that the Congress is going to be required to address, and the question is not whether, it's how do we address it.

And I appreciate very much your willingness to come. Some of you have traveled a long distance to just share with us some thoughts about what you are working on, and what we might consider in a different way when we consider the word carbon and CO2 and what we might do with it.

I, too, think that if we're smart, and we go about this the right way, we might well find that you can create an asset in terms of trying to deal with what we consider a liability.

If that's the case, we ought to run in that direction and say to those that are looking at sequestration: Good for you. Keep up your work as well, because we need to do a lot of everything to find out what works really well.

And the other piece I would say, finally, is this. It's one thing to do something in a laboratory. It's quite another thing to scale it up and demonstrate it at commercial scale. And even as we encourage the development in laboratories, we need to encourage the scaling up at commercial scale of those opportunities so that we know what do we have here? Does this work?

Then I think the private sector will beat a path to the door of that person who's demonstrated an idea that will provide the ability to make some money and sequester carbon at the same time.

Senator Bennett and I have a 10:00 markup at the Energy Committee that we have to attend.

And let me thank all of the witnesses for coming this morning, and your entire statement will be part of the record. And you may feel free to submit any additional material you wish for two weeks from the date of this hearing.

This hearing's adjourned. (Sounds gavel.)

END.