THE FUTURE OF COAL: UTILIZING AMERICA'S ABUNDANT ENERGY RESOURCES

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED THIRTEENTH CONGRESS

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C O N T E N T S

Thursday, July 25, 2013

THE FUTURE OF COAL: UTILIZING AMERICA'S ABUNDANT ENERGY RESOURCES

THURSDAY, JULY 25, 2013

House of Representatives,
Subcommittee on Energy
Committee on Science, Space, and Technology,
Washington, D.C.

The Subcommittee met, pursuant to call, at 9:36 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Cynthia Lummis [Chairwoman of the Subcommittee] presiding.A

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Subcommittee on Energy

The Future of Coal: Utilizing America's Abundant Energy Resources

Thursday, July 25, 2013
9:30 a.m. – 11:30 a.m.
2318 Rayburn House Office Building

Witnesses

Mr. Chris Smith, Acting Assistant Secretary for Fossil Energy, Department of Energy

Mr. Ben Yamagata, Executive Director, Coal Utilization Research Council

Mr. Don Collins, Chief Executive Officer, Western Research Institute

Ms. Judi Greenwald, Vice President, Center for Climate and Energy Solutions

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY

HEARING CHARTER

The Future of Coal: Utilizing America's Abundant Energy Resources

Thursday, July 25, 2013
9:30 a.m. – 11:30 a.m.
2318 Rayburn House Office Building

PURPOSE

The Subcommittee on Energy will hold a hearing entitled *The Future of Coal: Utilizing America's Abundant Energy Resources* on Thursday, July 25, at 9:30 a.m. in Room 2318 of the Rayburn House Office Building. The purpose of the hearing is to examine coal-related technology challenges and opportunities, with an emphasis on enhancing the effectiveness and impact of Department of Energy research and development (R&D) activities,[1] including DOE's R&D priorities as well as Federal government and private industry investments.

WITNESS LIST

- **Mr. Chris Smith,** Acting Assistant Secretary for Fossil Energy, Department of Energy
- **Mr. Ben Yamagata,** Executive Director, Coal Utilization Research Council
- **Mr. Don Collins,** Chief Executive Officer, Western Research Institute
- **Ms. Judi Greenwald,** Vice President, Center for Climate and Energy Solutions

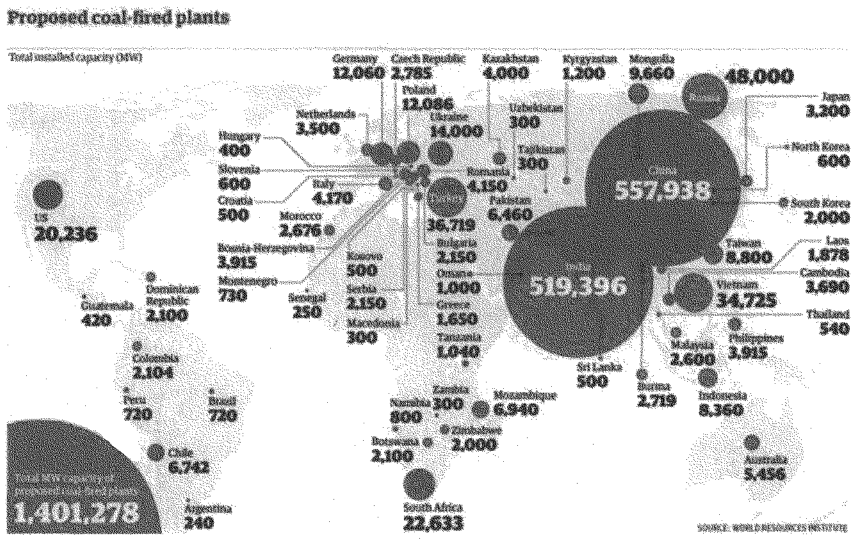
BACKGROUND

Coal currently generates approximately 40% of U.S. electricity, down from just under 50% in recent years.[2] The Energy Information Administration (EIA) projects nationwide demand for electricity will increase 28% through 2040, with coal's share of electric generation dropping to 35%. According to the World Resources Institute, total global proposed installation of coal-fired power plants is 1,401 gigawatts. The majority of these planned installations will be in India and China (Figure 1).

[1] For more information on coal-fired power plants, see Committee on Science Space and Technology hearing *"Advancing Coal research and Development for a Secure Energy Future"* October 13, 2011. Accessible at: http://science.house.gov/hearing/energy-and-environment-subcommittee-hearing-advancing-coal-research-and-development-secure

[2] Energy Information Administration, *"Annual Energy Outlook 2013,"* April 2013. Accessible at: http://www.eia.gov/forecasts/aeo/

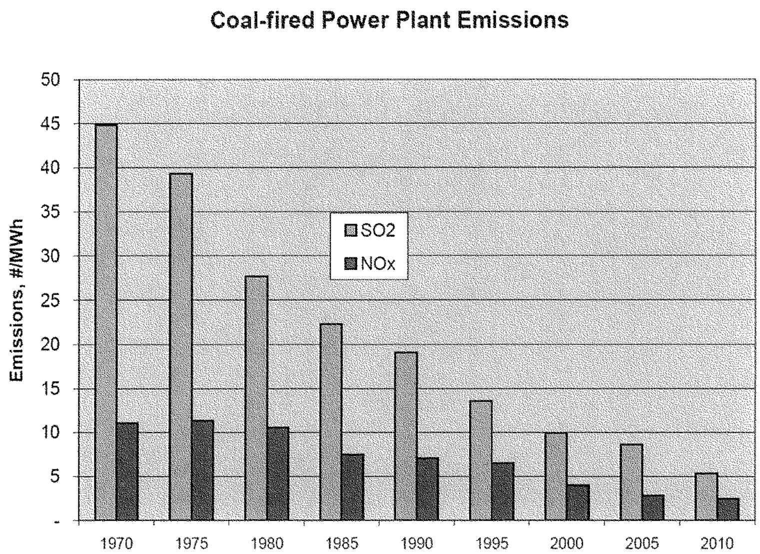
Figure 1: Proposed Coal-Fired Power Plants[3]



In recent decades, steady improvements to coal-related generation technologies have contributed significantly to increased efficiencies at power plants, a reduction of pollutant emissions (Figure 2), and reductions in water usage. For example, new power plants can handle higher temperature steam cycles, which increases efficiency to greater than 40% (up from approximately 30% for older plants). These improvements result in reduced environmental impacts per unit of electricity generated.

[3] The Guardian, *Which countries are planning the most coal-fired power plants?* November, 20, 2012. Accessible at: http://www.guardian.co.uk/environment/picture/2012/nov/20/which-countries-most-coal-power

Figure 2: Historical Coal Plant Emissions[4]



Department of Energy Coal Research and Development Activities

The Department of Energy funds a variety of coal research, development, and demonstration (RD&D) activities. DOE's Office of Fossil Energy (FE) is the primary office supporting coal RD&D. DOE FE's coal program mission is to "support secure, affordable, and environmentally acceptable near-zero emissions fossil energy technologies."[5]

In fiscal year 2013, DOE is supporting $495 million in fossil energy research and development activities, of which $370 million is directed to coal research, development and demonstration activities (Table 1). This funding is distributed between carbon capture ($69 million), carbon storage ($116 million), advanced energy systems ($100 million), and cross-cutting research activities ($49 million).

[4] *The CURC-EPRI Coal Technology Roadmap*, August 2012: Update, p. 9. Accessible at: http://www.coal.org/userfiles/file/FINAL%20Roadmap%20Report%20Update%20-%20August%202012%20(graphics%20and%20links).pdf

[5] Department of Energy, *"Department of Energy Budget Request Fiscal Year 2014, Volume 3"* p. FE-13, April 2013. Accessible at: http://energy.gov/sites/prod/files/2013/04/f0/Volume3_1.pdf

Table 1. Department of Energy (DOE) Fossil Energy Research and Development Spending
(dollars in millions)

Program	FY 2012 Current	FY 2013 Annualized CR	FY 2014 Request	FY 2014 House Energy & Water Bill	FY 2014 Senate Energy & Water Bill	FY 2014 Request versus FY 2012 Enacted	
						$	%
Coal							
CCS and power systems							
Carbon capture	*67.0*	*69.3*	*112.0*	*68.9*	*N/A*	*+45.0*	*+67.2%*
Carbon storage	*112.2*	*116.1*	*61.1*	*79.3*	*N/A*	*-51.1*	*-45.6%*
Advance energy systems	*97.2*	*100.6*	*48.0*	*91.7*	*40.0*	*-49.2*	*-50.6%*
Cross cutting research	*47.9*	*49.4*	*20.5*	*30.9*	*N/A*	*-27.4*	*-57.2%*
NETL coal research and development	*35.0*	*35.2*	*35.0*	*45.0*	*N/A*	*0*	*N/A*
Total, CCS and power systems	*359.3*	*370.7*	*276.6*	*315.9*	*268.6*	*-82.7*	*-23.0%*
Total, Fossil Energy R&D*	***337.1***	***495.0***	***420.6***	***450.0***	***420.6***	***+83.5***	***+24.8%***

* Total includes natural gas technologies, unconventional fossil energy technologies, program direction and use and rescission of prior year balances.

DOE also maintains a portfolio of major Carbon Capture and Sequestration (CCS) demonstration projects originally funded through the American Recovery and Reinvestment Act (Appendix A). Additionally, the Clean Coal Power Initiative (CCPI)—initiated in 2002 as a "cost-shared partnership between the Government and industry to develop and demonstrate advanced coal-based power generation technologies at the commercial scale"—has funded 18 projects, four of which remain currently active.[6]

DOE Advanced Fossil Energy Loan Guarantees

On July 2nd, the Department of Energy (DOE) announced a draft loan guarantee solicitation for advanced fossil energy projects and facilities.[7] The solicitation includes $8 billion in loan guarantees, authorized through section 1703 of the Energy Policy Act of 2005. The loan guarantees are intended to reduce greenhouse gas emissions and other air pollutants by financing the construction of advanced technology fossil energy projects and facilities. These include projects in areas such as advanced resource development, carbon capture, low-carbon power systems, and efficiency improvements with the goal to reduce emissions of carbon dioxide, methane, and other greenhouse gases.

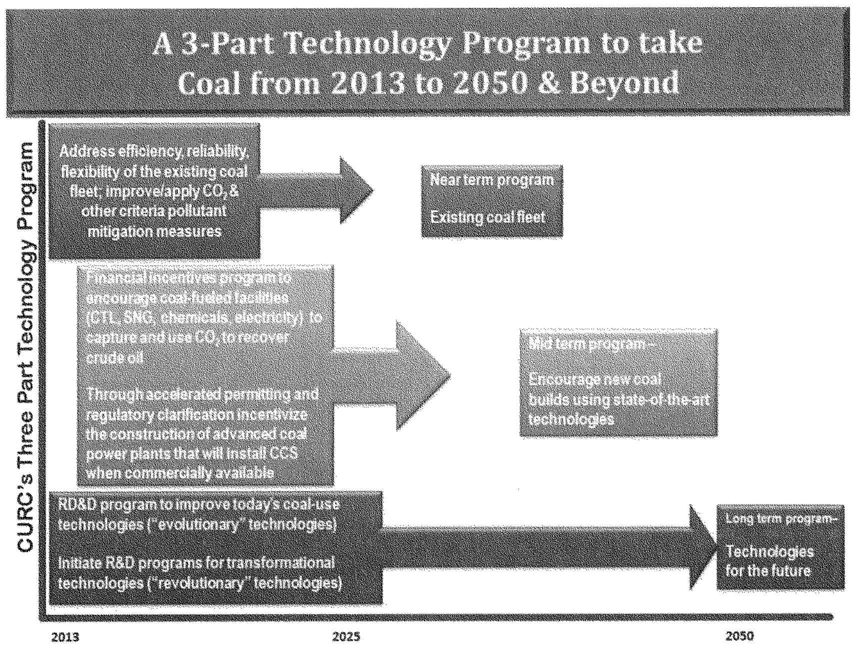
[6] Department of Energy, "Major Demonstrations: Clean Coal Power Initiative" Accessible at: http://www.netl.doe.gov/technologies/coalpower/cctc/ccpi/#

[7] Department of Energy, *"Energy Department Releases Draft Advanced Fossil Energy Solicitation to Support Reductions in Greenhouse Gas Pollution,"* July 2, 2013. Accessible at: http://energy.gov/articles/energy-department-releases-draft-advanced-fossil-energy-solicitation-support-reductions

Coal Technology Roadmap

In August 2012, the Coal Utilization Research Council (CURC) and Electric Power Research Institute (EPRI) updated their "*Coal Technology Roadmap*,"[8] originally drafted in 2000 and updated in 2008. The Roadmap "describes technologies needed to acquire a set of benefits from coal that each organization views as important and achievable through advancements in technology." The Roadmap identifies research, development and demonstration activities in various timeframes to reduce criteria pollutant emission, improve power plant efficiency, reduce water demand and discharge, and identify transformational technologies to reduce greenhouse gas emissions (Figure 3).

<u>*Figure 3: CURC/EPRI Coal Technology Roadmap Summary*</u>



[8] CURC/EPRI Coal Roadmap

Pending Regulatory Issues

On June 25, President Obama issued a Presidential memorandum directing the Environmental Protection Agency (EPA) to regulate greenhouse gas emissions from new and existing power plants.[9] Prior to this directive, the EPA had already taken steps to regulate greenhouse gas emissions from power plants. Last year, the EPA issued greenhouse gas New Source Performance Standards for new Electric Generating Units, which established carbon dioxide emissions standards for new fossil-fired power plants. These regulations would effectively limit the operation of existing or construction of new coal-fired power plants that do not have CCS technology. The following excerpt from Congressional Research Service report, *Carbon Capture and Sequestration: Research, Development, and Demonstration at the U.S. Department of Energy,* describes the connection between the proposed EPA regulations from new power plants and development of CCS technology:[10]

> *"In 2012 the U.S. Environmental Protection Agency (EPA) proposed a new rule that would limit emissions of carbon dioxide (CO2) to no more than 1,000 pounds per megawatt-hour of production from new fossil-fuel power plants with a capacity of 25 megawatts or larger. EPA proposed the rule under Section 111 of the Clean Air Act. According to EPA, new natural gas-fired combined-cycle power plants should be able to meet the proposed standards without additional cost. However, new coal-fired plants would only be able to meet the standards by installing carbon capture and sequestration (CCS) technology. EPA missed its original deadline for issuing a final rule and has not indicated when it will publish the final rule.*
>
> *The proposed rule sparked increased scrutiny of the future of CCS as a viable technology for reducing CO2 emissions from coal-fired power plants. It also placed a new focus on whether the U.S. Department of Energy's (DOE's) CCS research, development, and demonstration (RD&D) program will achieve its vision of developing an advanced CCS technology portfolio ready by 2020 for large-scale CCS deployment.*
>
> *Congress appropriated $3.4 billion from the American Recovery and Reinvestment Act (Recovery Act) for CCS RD&D at DOE's Office of Fossil Energy in addition to annual appropriations for CCS. The large influx of funding for industrial-scale CCS projects may accelerate development and deployment of CCS in the United States. Since enactment of the Recovery Act, DOE has shifted its RD&D emphasis to the demonstration phase of carbon capture technology. However, the future deployment of CCS may take a different course if the major components of the DOE program follow a path similar to DOE's flagship CCS demonstration project, FutureGen, which has experienced delays and multiple changes of scope and design since its inception in 2003.*

---

[9] The White House, *"The President's Climate Action Plan,"* June 2013. Accessible at: http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

[10] Congressional Research Service, *"Carbon Capture and Sequestration: Research, Development, and Demonstration at the U.S. Department of Energy,"* June 10, 2013. Accessible at: http://www.crs.gov/pages/Reports.aspx?PRODCODE=R42496

To date, there are no commercial ventures in the United States that capture, transport, and inject industrial-scale quantities of CO2 solely for the purposes of carbon sequestration. However, CCS RD&D has embarked on commercial-scale demonstration projects for CO2 capture, injection, and storage. The success of these projects will likely influence the future outlook for widespread deployment of CCS technologies as a strategy for preventing large quantities of CO2 from reaching the atmosphere while U.S. power plants continue to burn fossil fuels, mainly coal. Given the pending EPA rule, congressional interest in the future of coal as a domestic energy source appears directly linked to the future of CCS...

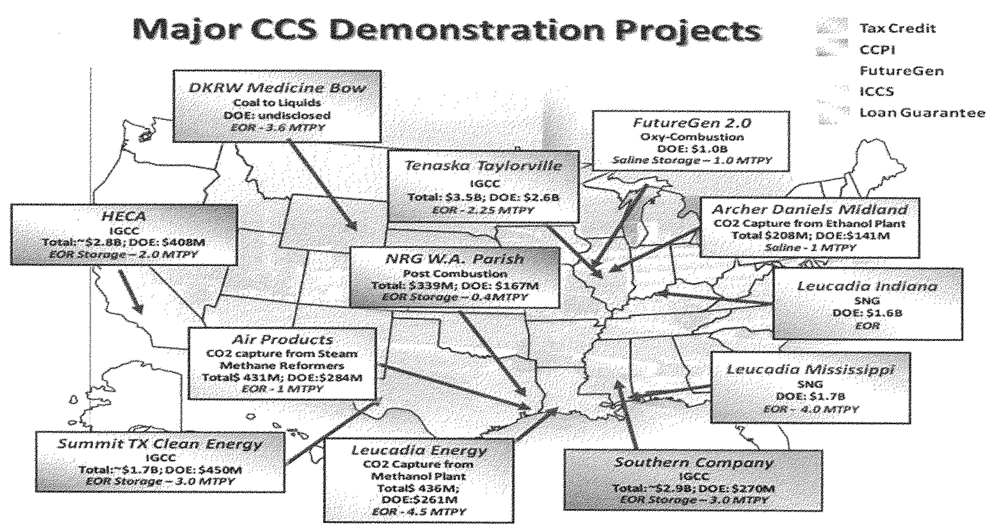
...Alternatively, congressional oversight of the CCS RD&D program could help inform decisions about the level of support for the program and help Congress gauge whether it is on track to meet its goals. A DOE Inspector General audit report identified several weaknesses in the DOE management of awards made under the Industrial Carbon Capture and Storage (ICCS) program funded by the Recovery Act. The audit report noted that addressing these management issues would be important to future management of the program, given that DOE had only obligated about $623 million of the $1.5 billion appropriated for the ICCS program under the Recovery Act as of February 2013."

ADDITIONAL READING

- Congressional Research Service, *Carbon Capture and Sequestration (CCS): A Primer*. July 16, 2013. http://www.crs.gov/pdfloader/R42532
- Coal Utilization Research Council: *The CURC-EPRI Coal Technology Roadmap*, August 2012. http://www.coal.org/userfiles/file/FINAL%20Roadmap%20Report%20Update%20-%20August%202012%20(graphics%20and%20links).pdf

Appendix A[11]

Attachment 2. Federally Supported CCS Demonstration Projects Currently Under Development



*Additional Advances Coal Demonstration Projects include Duke Edwardsport IGCC (no C02 capture component) and Tenaska Trailblazer Energy Center (no public funds received)

[11] CURC-EPRI Roadmap.

Chairman LUMMIS. Good morning. Welcome to today's hearing titled "The Future of Coal: Utilizing America's Abundant Energy Resources." And now the Subcommittee on Energy will come to order.

In front of you are packets containing the written testimony, biographies and Truth in Testimony disclosures of today's witness panel. I now recognize myself for a five minute opening statement and then I will turn it over to my Ranking Member, Mr. Swalwell. Thank you all for being here, and we will have others trickling in as the morning goes on.

Coal is of critical importance to the United States. From Thomas Edison's construction of the world's first electric power plant in 1892, through today, coal has led the way in enabling the enormous improvements to Americans' health and well-being. It remains our leading source of affordable and reliable electricity, providing a foundation for our national and economic security while directly supporting hundreds of thousands of jobs and powering industrial facilities that produce the inexpensive goods we too often take for granted so middle- and lower-income Americans can enjoy a higher standard of living and make their hard-earned dollars go farther.

Rarely, however, has such a beneficial, life-improving resource upon which society depends been under such hostile attack. Adding injury to insult, this attack is being led by our own President. In 2008, President Obama boasted on the campaign trail that his policies would necessarily bankrupt any company that wanted to build a coal-fired power plant.

Unfortunately, this is one campaign promise that the President appears determined to keep. Not only are his EPA power plant regulations effectively prohibiting new coal plants from being constructed, they are imposing massive costs on existing plants and forcing scores of shutdowns. For example, 288 coal units in 32 states cited current and pending EPA regulations as a factor contributing to their expected closure.

Senior members of the Obama Administration have readily acknowledged the negative impacts of these policies. For example, former DOE Deputy Assistant Secretary for Fossil Energy Jim Wood estimated that EPA rules could force up to—excuse me—that EPA rules could force up to 70 gigawatts of coal offline, adding: "Number one, electric rates are going to go up. Number two, whether or not construction jobs in the green industry are created, I think there are virtually no manufacturing jobs that are likely to be created from the replacement of coal. Three, transmission grid stability is likely to emerge as a major issue, both because of the shutdowns and because of the intermittency of renewables."

EPA is just one agency leading the war on coal. On Tuesday, the House Natural Resources Committee discussed the Department of Interior's anti-coal regulations that would restrict coalmining activities and result in thousands of lost jobs in the coalmining industry.

Incredibly, the President is even attempting to limit the global use of coal by restricting international aid for it in developing countries, thus limiting access to the primary means through which those countries' citizens escape poverty.

Even if the President were successful in his quest to eliminate all U.S. coal-fired power plants, any potential reductions in projected global warming would more than undertaken by global emission growth. China continues to build a coal plant a week, and global coal demand is projected to continue to grow significantly over the next half century, regardless of U.S. domestic policy.

The purpose of today's hearing, and the challenge before us in this Subcommittee, is to apply these regulatory, economic and global realities to improve the focus and prioritization of DOE's coal related activities. To this end, I look forward to hearing more about the recently developed coal R&D roadmap and how it could help identify technology opportunities to increase efficiencies, reduce pollutants, minimize water consumption, and lower the cost of electricity.

I am also eager to examine in more detail the truly innovative research underway at the Western Resources Institute in Wyoming. WRI serves as a model of how to bring together public, private and academic stakeholders to advance development and use of abundant and affordable energy supplies.

[The prepared statement of Mrs. Lummis follows:]

PREPARED STATEMENT OF SUBCOMMITTEE CHAIRMAN CYNTHIA LUMMIS

Good morning and welcome to this morning's hearing titled The Future of Coal: Utilizing America's Abundant Energy Resources.

Coal is of critical importance to the United States. Since the founding of our country, through Thomas Edison's construction of the world's first electric power plant in 1892, and continuing still today, coal has led the way in enabling the enormous improvements to Americans' health and well-being. It remains our leading source of affordable and reliable electricity, providing a foundation for our national and economic security while directly supporting hundreds of thousands of jobs and powering industrial facilities that produce the inexpensive goods we too often take for granted.

Rarely, however, has such a beneficial, life-improving resource upon which society depends been under such hostile attack.

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Thank you, and I now yield to Ranking Member Swalwell for his opening statement.

Chairman LUMMIS. Thanks, and I now yield to Ranking Member Swalwell for his opening statement.

Mr. SWALWELL. Thank you, Chairman Lummis, and first, I ask unanimous consent that Ranking Member Johnson of the Full Committee, that her opening statement be entered into the record. She will not be able to be here today but has been a leader in this area, and I hope the Committee will accept that.

Chairman LUMMIS. Accepted.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY RANKING MEMBER EDDIE BERNICE JOHNSON

Thank you, Chairman Lummis for holding this hearing today. I would also like to thank all the witnesses for coming in to discuss the future role of coal in the United States.

I am pleased, in particular, to welcome Ms. Judi Greenwald, who will be able to tell us more about some important projects in the great State of Texas—where we have seen the value of coal energy, but also its negative impacts.

Coal has been an abundant and important source of energy through much of our Nation's history, and that is why I support the Department of Energy's efforts to make our use of coal cleaner and more efficient even as we lay the foundation for a more sustainable energy future.

I am not here to promote one industry over another. Instead, I believe we must promote policies that protect our environment, meet our energy needs, and keep Americans working.

We must do more than just keep the lights on. We need to work towards an energy future that recognizes that our environment is changing, in part due to our past energy usage.

Record droughts and severe storms are sadly becoming too common, but I and many of my colleagues here today stand determined to do everything we can to curb the man-made causes of climate change and give our future generations a sense of environmental security while still providing them with a strong economy.

So I look forward to hearing from our witnesses today on what we are doing, and what still needs to be done, to ensure that our mature coal industry follows the lead of our vibrant renewable energy sector in developing the environmentally responsible energy sources of today, and tomorrow.

Mr. SWALWELL. Thank you, I also wanted to thank you for holding this hearing, and I want to thank the witnesses for their testimony today, and I am pleased also to welcome Ms. Judi Greenwald from the Center for Climate and Energy Solutions, a group that does a lot of work in Texas, the home state of our Full Committee Chairman Mr. Smith, our Ranking Member, Ms. Johnson, and my colleague on this Subcommittee, Mr. Veasey, and Mr. Veasey will introduce Ms. Greenwald in a moment.

This morning before I came over here, I had some students in my office, just part of a constituent thing that we do about a couple times a month, and they asked where I was going and I told them I was going to this hearing on coal, and these are students from my district. They kind of had this puzzling look on their face, and I said yes, that is right, coal. You know, I know you are from California, we don't necessarily rely upon coal as our energy resource but the rest of the country and many places does, and I explained to them that we are at this point right now in our country where we are in a struggle and a pull, and we are trying to figure out where are we going to provide, how are we going to provide the future of our energy needs, and in California, we are proud that 20 percent of our electricity in 2009, the last study that was available, was provided by renewables. And so California has always seen ourselves as kind of leading the country forward and moving away from dirty fossil fuels that could hurt the environment and not be so good for our children or the future. But coal does have a place to play, and I am interested and have always agreed that the all-of-the-above approach is the way we should go, and wherever we can make it safe, we should make it happen, and I support the chair's interest in doing this.

But I say that what the President talked about a couple weeks back with climate change was not a war on coal. In fact, I saw it as the opposite. I saw it as a retreat from coal, not a war on coal but an attempt for the United States to eventually one day hopefully pull out of coal and pull closer to more renewable, cleaner energy sources, and that is what I support. But until that day comes, I will continue to work with our chair to find a future of coal that is clean and good for our environment, and we should not ignore the possibilities available today as we continue to move and strive for the fuels of tomorrow. And programs like the National Enhanced Oil Recovery Initiative demonstrate their innovative capabilities of a mature coal industry that has long enjoyed Federal support. Carbon capture and storage and enhanced oil recovery are examples of important technologies that will help ensure that our present reliance on coal will not hinder our ability to move towards a cleaner, safer environment. These advances also support Americans working in these industries today, even as we lay the foundation for emerging energy technologies that will support the workforce of the future.

So I look forward to working with you, Chair, on doing this, hearing from our witnesses and making progress in this area, and with that, I yield back the balance of my time.

[The prepared statement of Mr. Swalwell follows:]

PREPARED STATEMENT OF SUBCOMMITTEE RANKING MEMBER ERIC SWALWELL

Thank you, Chairman Lummis, for holding this hearing. I want to also thank the witnesses for their testimony and for being here to answer our questions today. I am pleased to welcome Ms. Judi Greenwald, from the Center for Climate and Energy Solutions, a group that does a lot of work in Texas, the home state of our Full Committee Chairman Mr. Smith, our Ranking Member Ms. Johnson, and my colleague on this Subcommittee, Mr. Veasey.

This hearing is an opportunity to demonstrate the value of a true "all-of-the-above" approach to energy production, which has to include taking the necessary steps to make existing fuel technologies cleaner and more efficient. I am a strong supporter of the policies that have helped my state of California see growth in the solar and wind energy sectors, which provide clean energy to millions while meeting the job demands of a growing workforce. However, we should not ignore the possibilities available today as we move towards the fuels of tomorrow.

Programs like the National Enhanced Oil Recovery Initiative demonstrate the innovative capabilities of a mature coal industry that has long enjoyed federal support. Carbon capture and storage and enhanced oil recovery are examples of important technologies that will help ensure that our present reliance on coal will not hinder our ability to move towards a cleaner, safer environment. These advances also support Americans working in these industries today, even as we lay the foundation for emerging energy technologies that will support the workforce of the future.

I look forward to learning more from our witnesses about progress being made in this area, and with that, I yield back the balance of my time.

Chairman LUMMIS. Thank you, Mr. Swalwell.

We have not seen the chairman of the Full Committee, Mr. Smith, come in. We have accepted the statement of the Ranking Member of the Full Committee. If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point. Thank you. We will begin then.

I would like to introduce our witnesses, and I will defer to Mr. Veasey when he arrives—excellent. Your opportunity to introduce Ms. Greenwald will be occurring shortly.

Our first witness toady is Chris Smith, Acting Assistant Secretary for Fossil Energy at the Department of Energy. Mr. Smith was appointed in 2009 as Assistant Secretary for Fossil Energy's Office of Oil and Natural Gas. Prior to joining DOE, Mr. Smith spent 11 years with international oil companies focused on upstream business development and LNG trading.

Our second witness is Ben Yamagata. Did I get that right, Mr. Yamagata?

Mr. YAMAGATA. Yes, Madam Chair.

Chairman LUMMIS. Thank you. Executive Director at the Coal Utilization Research Council. Mr. Yamagata is also a partner at Van Ness Feldman, where his practice encompasses energy, environment and natural resources. He has also served as Counsel and Staff Director for the Senate Energy and Natural Resources Subcommittee on Energy Research and Development.

Our third witness is Don Collins, Chief Executive Officer at the Western Research Institute. Mr. Collins focuses on transitioning scientific and applied research into technologies. He has spent 29 years of experience in engineering, management of research and deploying of new technologies.

And for today's final witness, Judi Greenwald, I yield to the gentleman from Texas, Mr. Veasey.

Mr. VEASEY. Thank you, Madam Chair, and before I introduce Ms. Greenwald, I would be remiss if I did not mention that Mr. Smith is from Fort Worth, my hometown in Texas, just outside of Dallas, and I am happy to have him on the panel today, and I wanted to introduce Judi Greenwald. Judi is the Vice President for Technology and Innovation at the Center for Climate and Energy Solutions. She oversees very many important aspects of that organization including the analysis and promotion of innovation in the major sectors that contribute to climate change including transportation, electric power, buildings and industry. In addition to her 30 years of working on environmental and energy policy, she also has a strong Texas connection and has worked with many organizations and individuals in our great state, and I want to welcome her here this morning.

Thank you, Madam Chair.

Chairman LUMMIS. Thank you, Mr. Veasey.

And now we will go to our witnesses. As you may know, spoken testimony is limited to five minutes each after which the Members of the Committee will have five minutes each to ask questions.

We welcome you here today, Mr. Smith. You are recognized first to present your testimony. My favorite boot store in all of America is in Fort Worth, and we are delighted to have a good Fort Worth native amongst us. So Mr. Smith, you are now recognized for five minutes.

TESTIMONY OF MR. CHRIS SMITH, ACTING ASSISTANT SECRETARY FOR FOSSIL ENERGY, DEPARTMENT OF ENERGY

Mr. SMITH. Well, thank you, Chairwoman Lummis. Lots of Fort Worth references this morning, so I am happy with that.

So thank you, Chairwoman, and thank you, Ranking Member Swalwell and Members of the Subcommittee, and I appreciate this opportunity to discuss Department of Energy's coal research and development activities.

Recently, our Secretary, Secretary Ernie Moniz, announced an $8 billion draft loan guarantee solicitation to promote the early development and deployment of innovative fossil energy projects that reduce carbon emissions. This solicitation in addition to the $6 billion the Obama Administration has already committed to clean coal technologies reflects the President's commitment to an all-of-the-above strategy that embraces an energy mix of nuclear power, renewable energy sources and fossil fuel, including clean coal.

The Department of Energy continues to play a leadership role in the development of clean coal technologies with a focus on carbon capture and storage, or CCS. The Clean Coal Research program, in partnership with the private sector, is focused on maximizing efficiency and environmental performance while minimizing the costs of these new technologies. In recent years, the program has been restructured to focus on clean coal technologies with carbon capture and sequestration. The program pursues the following two major strategies: first, capturing and storing greenhouse gases, and second, improving the efficiency of fossil energy systems.

The Clean Coal Research program is addressing the key challenges that confront the development and deployment of clean coal technologies through research on cost-effective capture technologies, monitoring, verification and accounting technologies to ensure permanent storage and the development of advanced energy systems. To get there, we are pursuing these three technical pathways for carbon capture: post-combustion, pre-combustion and oxy-combustion. Research in these pathways is exploring a wide range of approaches that, coupled with advances in efficiency improvements and cost reductions from developments in gasification turbines, will help provide a technology base for the commercial deployment of CCS technologies.

On the storage side, we have pursued projects to develop and design innovative advanced technology and protocols for the monitoring, verification, and accounting of CO_2 storage in geologic formations as well as simulating the behavior of geologically stored CO_2. Our original carbon sequestration partnerships are an essential component of that effort. The program is currently in the development phase during which large-scale field testing involving at least 1 million metric tons of CO_2 per project will be implemented. Several of these large-scale tests are currently underway, and one project has safely injected over 3.6 million metric tons and is being monitored for safe and permanent storage.

The Department is implementing large-scale projects for their regional partnerships, the Clean Coal Power Initiative, FutureGen 2.0, and the Industrial Carbon Capture and Storage program. We currently have eight major CCS demonstration projects nationwide, and there have been important advances in several of them. For example, the Archer Daniels Midland ICCS project in Illinois will demonstrate an integrated system of CCS in an ethanol production plant. The project is under construction and is nearly 50 percent complete. FutureGen 2.0 has successfully completed phase I, and phase II commenced in February of this year. The project is now focused on the preliminary design and engineering.

Current demonstrations are focused on storing CO_2 in a variety of geologic formations including enhanced oil recovery. Enhanced oil recovery represents the most commercially attractive utilization option for CO_2 storage that could produce substantial quantities of oil while permanently storing CO_2 in geologic formations. There are currently six projects employing CO_2 EOR and two projects employing saline storage underway across the United States. And as with saline storage projects, CO_2 EOR projects will be subject to rigorous monitoring, verification, accounting procedures, and technologies to ensure their safety and effectiveness.

Today, nearly three out of four coal-burning power plants in this country are equipped with technologies that can trace their roots back to the Department of Energy's advanced coal technology program. The Office of Fossil Energy's ongoing mission is to ensure that this important resource can be developed and utilized in an environmentally sensible way to strengthen our Nation's energy security, and I believe that our Clean Coal Research program demonstrates that we have the critical experience, expertise and capabilities, and the track record to meet this challenge.

Madam Chairwoman and Members of the Committee, that completes my prepared statement, and I would be happy to answer any questions that you may have.

[The prepared statement of Mr. Smith follows:]

Statement of Christopher Smith
Assistant Secretary for Fossil Energy (Acting)
U.S. Department of Energy

Before the
Committee on Science, Space and Technology
Subcommittee on Energy

U.S. House of Representatives

Coal Research and Development

July 25, 2013

Thank you Chairman Lummis, Ranking Member Swalwell, and members of the Subcommittee. I appreciate the opportunity to discuss the Department of Energy's (DOE) coal research and development (R&D) activities.

Coal fuels approximately 40 percent of our domestic electricity production. As the Energy Information Administration (EIA) recently pointed out in the Annual Energy Outlook 2013 reference case, coal is projected to remain the largest energy source for electricity generation through 2040.[1] Because it is abundant, the clean and efficient use of coal is a key part of President Obama's all-of-the-above energy strategy.

A major challenge to coal, however, is that it is a major source of carbon dioxide (CO_2) emissions. Therefore, it is critical that we promote currently available technologies and develop more economic and broadly available technologies to reduce those emissions from coal-fired power plants. To that end, the Obama Administration strongly supports the development of clean coal technologies, including carbon capture and storage (CCS). In addition to the Administration's annual budget requests, that support was made clear in the 2009 American

[1] "Annual Energy Outlook 2013," Energy Information Administration.

Recovery and Reinvestment Act (Recovery Act), which provided $3.4 billion for CCS. It was also evident in the formation of the Interagency Task Force on Carbon Capture and Storage, which the President charged in February 2010 to develop a plan to overcome the barriers to the widespread, cost-effective deployment of CCS within 10 years.

On June 25, President Obama laid out a broad Climate Action Plan to cut carbon pollution in America, prepare the United States for the impacts of climate change, and lead international efforts to combat global climate change and prepare for its impacts. A key component of that plan is an $8 billion draft loan guarantee solicitation which is designed to support investments in innovative technologies that can cost-effectively meet financial and policy goals, including the avoidance, reduction, or sequestration of anthropogenic emissions of greenhouse gases. The proposed solicitation will cover a broad range of advanced fossil energy projects. The draft solicitation was released on July 2, commencing a 60 day public comment period.

As the President has made clear, fossil fuels – including coal – provide more than 80 percent of our energy today and they are projected to remain a large source of energy for decades. The fossil solicitation – in addition to the $6 billion the Administration has already committed to clean coal technologies - reflects the Administration's commitment to "all of above" energy strategy that develops every available source of American energy -- a strategy that's cleaner, cheaper, and full of new jobs.

Clean Coal Research Program

DOE continues to play a leadership role in the development of clean coal technologies with a focus on CCS. The Clean Coal Research Program – administered by DOE's Office of Fossil Energy and implemented by the National Energy Technology Laboratory – is designed to enhance our energy security and reduce environmental concerns over the future use of coal by developing a portfolio of revolutionary clean coal technologies. The Program is well positioned to help overcome the technical challenges associated with the development of clean coal technologies.

The Clean Coal Research Program, in partnership with the private sector, is focused on maximizing efficiency and environmental performance, while minimizing the costs of these new technologies. In recent years, the Program has been restructured to focus on clean coal technologies with CCS. The Program pursues the following two major strategies:

1) capturing and storing greenhouse gases; and
2) improving the efficiency of fossil energy systems.

The first strategy aims to remove emissions of greenhouse gases from fossil fueled energy systems. The second strategy seeks to improve the fuel-to-energy efficiencies of these systems, thus reducing pollutant emissions, water usage, and carbon emissions on a per unit of energy basis. Collectively, these two strategies comprise the Clean Coal Research Program's approach to ensure that current and future fossil energy plants can contribute to a safe and secure clean energy future.

Core Research and Development Activities

The Clean Coal Research Program is addressing the key challenges that confront the development and deployment of clean coal technologies through research on cost-effective capture technologies; monitoring, verification, and accounting technologies to ensure permanent storage; and development of advanced energy systems. As an example, today's commercially available CO_2 capture technologies are projected, after experience gained from multiple plant installations, to increase the cost of electricity by as much as 70 percent for a new coal-fueled power plant (equivalent to about $60 per tonne of CO_2 captured) This cost is for removing 90 percent of the CO2 emissions and exclusive of any expenses associated with transporting and storing the captured CO_2, but it also omits potentially material benefits from using the CO2 for enhanced oil recovery, as discussed in detail below[2,3] Recognize that capturing less than 90 percent CO2 emissions from either a new or existing power plant will reduce the cost of electricity penalty, as expected. However, installing a smaller unit to remove less CO2 emissions will result in an increase in avoided CO2 mitigation costs due to the loss of "economies of scale" savings associated with the larger capital equipment. The Program is aggressively pursuing developments that would reduce the cost penalty for electricity from new coal-fueled power plants with carbon capture from roughly 70 percent to about 35 percent (equivalent to about $40 per tonne of CO_2 captured).

Research is focused on developing technology options that dramatically lower the cost of capturing carbon dioxide from fossil fueled energy plants. This research can be categorized into three technical pathways: post-combustion, pre-combustion, and oxy- combustion. Post-combustion refers to capturing CO_2 from the stack gas after a fuel has been combusted in air. Pre-combustion refers to a process where a hydrocarbon fuel is gasified to form a mixture of hydrogen and carbon dioxide, and CO_2 is captured from the synthesis gas before it is combusted. Oxy-combustion is an approach where a hydrocarbon fuel is combusted in pure or nearly pure oxygen rather than air, which releases energy and produces a mixture of CO_2 and water that can easily be separated to produce pure CO_2.

Collectively, research in each of these technical pathways is exploring a wide range of approaches such as membranes; oxy-combustion concepts; solid sorbents; advanced gas/liquid scrubbing technologies; and advanced hybrid concepts such as liquid membrane contactors.

These efforts cover not only improvements to state-of-the-art technologies but also development of several revolutionary concepts, such as metal organic frameworks, ionic liquids, enzyme-based systems, and chemical looping – a form of oxy-combustion that utilizes oxygen from metal oxide oxygen carrier for fuel combustion, or for making hydrogen by "reducing" water. In combustion applications, the products of chemical looping are CO_2 and H_2O. Thus, once the steam is condensed, a relatively pure stream of CO_2 is produced ready for sequestration.

Coupling these developments with other advances in efficiency improvements and cost reduction from developments in gasification and turbines, will help provide a technology base that overcomes economic barriers to commercial adoption of fossil energy systems integrated with CCS.

Regional Carbon Sequestration Partnerships

The Regional Carbon Sequestration Partnerships were created by DOE in 2003 through a competitive solicitation. The Partnerships were designed to address a range of issues associated with geologic storage of CO_2. The Clean Coal Research Program has been performing CCS field tests focused on injection, monitoring, verification, accounting and other aspects of geologic storage for many years, and the seven Regional Carbon Sequestration Partnerships are critical to this effort. These Partnerships are comprised of state agencies, universities, and private companies. They represent more than 400 unique organizations in 43 States, and four Canadian Provinces. Geographic differences in fossil fuel use and potential storage sites across the United States dictate the use of regional approaches in addressing CCS, so each Partnership is focused on a specific region of the United States and Canada that holds similar characteristics relating to CCS opportunities.

Together, the Partnerships form a network of capability, knowledge, and infrastructure that will help enable geologic storage technology to play a role in the clean energy economy. They represent regions encompassing 97 percent of coal-fired CO_2 emissions, 97 percent of industrial CO_2 emissions, 96 percent of the total land mass, and essentially all the geologic storage sites that can potentially be available for geologic carbon storage.

During the Validation Phase of the program, Regional Partnerships drilled wells and injected small quantities of CO_2 to validate the potential of key storage locations totaling more than 1 million metric tons of CO_2 at 18 small scale injection projects throughout the United States and Canada. Those tests helped to validate storage at a small scale to understand the fate of CO_2 in different depositional systems containing saline water, oil, and natural gas. The program is currently in the Development Phase, during which large-scale field testing involving at least 1 million metric tons of CO_2 per project will be injected. Tests are designed to not only investigate commercial-scale injection of CO_2, but will also be used to understand the necessary regulatory, economic, liability, ownership, and public outreach efforts needed for successful CCS, and to develop the necessary human capital, knowledge base, and experience necessary to implement future CCS operations. Several of the large-scale tests are currently underway and one project has safely injected over 3.6 million metric tons and is being monitored for safe and permanent storage.

Over the course of these initiatives, DOE and the Partnerships are addressing key infrastructure issues related to permitting, pore space ownership, site access, liability, public outreach, and education. We are also jointly developing Best Practice Manuals on topics such as site characterization, site construction, operations, monitoring, mitigation, closure, and long-term stewardship. These Manuals will serve as guidelines for a future geologic sequestration industry in their regions, and help transfer the lessons learned from DOE's Clean Coal Research Program to all regional stakeholders. The first editions of the Best Practice Manuals are available on DOE's reference shelf[4] and the Manuals will be periodically updated as lessons learned from the large scale field tests are realized.

We have also pursued projects designed to develop technologies and protocols for the monitoring, verification, accounting, and assessment (MVAA) of CO_2 storage in geologic formations as well as simulating the behavior of geologically-stored CO_2. MVAA of geologic storage sites is an important part of making geologic storage a safe, effective and reliable method of greenhouse gas control. These activities will culminate in a set of best practices for the deployment of carbon capture, utilization and storage technology.

Finally, DOE and the Partnerships continue to work closely with the Environmental Protection Agency (EPA) and other Federal and state agencies in developing CCS regulatory strategies, which will provide additional certainty for future CCS deployments.

Demonstrations at Commercial-Scale

The success of the Clean Coal Program will ultimately be judged by the extent to which emerging technologies get deployed in domestic and international marketplaces. Both technical and economic challenges associated with the deployment of newer coal technologies must be overcome in order to be capable of achieving success in the marketplace. Commercial-scale demonstrations help the industry understand and overcome start-up issues, address component integration issues, and gain the early learning commercial experience necessary to reduce technology risk and secure private financing and investment for future plants.

The Department is implementing commercial-scale demonstration projects through the Clean

[4] http://www.netl.doe.gov/technologies/carbon_seq/refshelf/refshelf.html

Coal Power Initiative (CCPI), FutureGen 2.0, and the Industrial Carbon Capture and Storage (ICCS) program.

The CCPI is a cost-shared partnership between the Government and industry to develop and demonstrate advanced coal-based power generation technologies at the commercial scale. By enabling advanced technologies to overcome technical risks involved with scale-up and bringing them to the point of commercial readiness, CCPI accelerates the development of advanced coal generation technologies integrated with CCS. The CCPI also facilitates the movement of technologies into the marketplace that are emerging from the core research and development activities.

The CCPI program received an additional $800 million from the Recovery Act which, in combination with base funding, was used to fund four CCPI Round III projects, of which two pre-combustion and one post-combustion capture projects are still active. In addition, a CCPI Round II project, with Southern Company Services, was modified to demonstrate CCS at a new integrated gasification combined cycle power plant. Having completed all design, planning, and environmental review requirements, this project began construction in 2010 and project construction is now 63 percent complete.

The FutureGen 2.0 Project intends to conduct novel large-scale testing to accelerate the deployment of advanced oxy-combustion power production technologies integrated with CCS. This project will be the first advanced repowering oxy-combustion project to store CO_2 in a deep saline geologic formation. On August 5, 2010, then-Secretary of Energy Steven Chu announced an award totaling $1 billion in Recovery Act funding to 1) The FutureGen Alliance and 2) Ameren Energy Resources along with their partners (Babcock & Wilcox and Air Liquide Process and Construction, Inc.) to repower an existing plant with advanced oxy-combustion technologies.

Together, these two awards comprised the FutureGen 2.0 project for clean coal repowering with CCS. On February 28, 2011, the FutureGen Alliance selected Morgan County, Illinois, as the preferred location for the FutureGen 2.0 CO_2 storage site, visitor center, and research and training facilities. The Alliance has subsequently taken over leadership of both projects comprising the FutureGen 2.0 program.

FutureGen 2.0 has successfully completed Phase I, which included identification of a sequestration site, preliminary characterization and test drilling, and a commitment from the Illinois Commerce Commission to cover the project's output under its purchasing plans. Phase II commenced on February 1, 2013, and the project is now focused on preliminary design and engineering.

In addition to the CCPI and FutureGen 2.0 projects, the Recovery Act has also helped fund more than 80 additional projects, which includes three large scale ICCS demonstrations, 10 geologic site characterizations, 43 university research training projects, seven CCS research training centers, six ICCS projects focused on CO_2 reuse, and 14 projects focused on accelerated component development in the core research program.[5]

Examples of progress on these projects include the Archer Daniels Midland ICCS project in Illinois, which will demonstrate an integrated system of CO_2 capture in an ethanol production plant and geologic sequestration in a sandstone reservoir. This project is under construction and approximately 49 percent complete. In Texas, the Air Products and Chemicals, Inc. ICCS project recently began capturing CO_2 from two steam methane reformer hydrogen production plants for enhanced oil recovery (EOR) operations. This project is the first to capture CO_2 at large scale from steam methane reformers used for hydrogen production, with the captured CO_2 then utilized for EOR.

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[5] Details about all of the Fossil Energy projects funded by the Recovery Act can be found here: http://energy.gov/fe/fe-implementation-recovery-act.

CO_2 Utilization Technologies

The coal research and development program has supported research on CO_2 utilization technologies for more than a decade. When the Carbon Storage Program (formerly named the Sequestration Program) was initiated in the mid-1990s, it was recognized that technologies such as mineralization, chemical conversion to useful products, algae production, enhanced oil recovery and enhanced coal bed methane recovery could play an important role in mitigating CO_2 emissions. Other than EOR, the CO_2 emissions reduction potential of these approaches is limited, due to factors such as cost and market saturation of salable byproducts. Even so, these approaches are logical "first-market entry" candidates for greenhouse gas mitigation, due to their ability to produce revenue from use of the CO_2 that could be used to offset the costs for these "early adopters." Hence, these options provide a technology bridge and smoother transition to the deployment of the large-scale, stand-alone geologic sequestration operations that will ultimately be needed to achieve the much larger emissions reductions required to approach stabilizing greenhouse gas concentrations in the atmosphere.

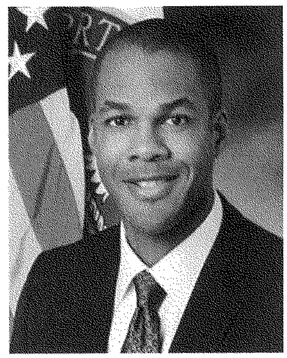
EOR represents the most near term and most commercially attractive utilization option for captured CO_2. Over the history of the Department, the focus of CO_2-EOR R&D has shifted from increased incremental oil production to monitoring, verification, and accounting of geologically stored CO_2 as part of a climate change mitigation strategy. As early as the 1970s, DOE-funded projects were developing concepts to improve the effectiveness and applicability of CO_2-EOR. Currently, most commercial EOR projects have been strategically located near cheap sources of naturally occurring CO_2 or along pipelines from such sources. If research into reducing the cost of CO_2 capture from power plants proves successful, anthropogenic sources of CO_2 may become readily available for EOR projects. The DOE's 2012 Carbon Utilization and Storage Atlas of the United States projects a potential CO_2 storage resource estimate of over 200 billion tonnes for oil and gas reservoirs in the United States. In the near-term, incremental oil produced via EOR using anthropogenic CO_2 could help offset the costs of CO_2 capture. The prospect of relatively low-cost supplies of captured CO_2 in widespread areas of the country could, in turn, provide the impetus for a national re-evaluation of the EOR potential in many mature fields. While conventional EOR is a widely used process, CO_2 capture and permanent storage is not yet widely used at power plants. Continued evolution of EOR and transformational advances in development and deployment of CO_2 capture from coal power on a large scale could help realize the synergy between the coal/power industry and the oil industry. Utilization of the CO_2 in EOR will impart knowledge that will be instrumental in the Department's continued focus on R&D in other geologic storage formations such as saline that have a larger storage potential for CO_2.

Conclusion

Today, nearly three out of every four coal-burning power plants in this country are equipped with technologies that can trace their roots back to DOE's advanced coal technology program. These efforts helped accelerate production of cost-effective compliance options to address legacy environmental issues associated with coal use. CCS and related clean coal technologies can play a critical role in mitigating CO_2 emissions under many potential future carbon stabilization scenarios. CO_2 utilization technologies with salable byproducts are logical "first market entry" candidates for greenhouse gas mitigation due to their ability to produce revenue from the use of CO_2. EOR will be the dominant utilization opportunity in the near term and will impart additional experience that will be useful in the Department's continued focus on R&D in other storage formations, such as deep saline aquifers, necessary to address climate change. Nevertheless, challenges remain to promote currently available technologies and develop more economic and broadly available technologies for deployment of CCS. The Department's research programs and efforts have spearheaded R&D that would not have occurred otherwise and has successfully leveraged private investment in advancing the readiness of these emerging clean coal technologies.

Mr. Chairman, and members of the Committee, this completes my prepared statement. I would be happy to answer any questions you may have at this time.

Christopher Smith
Assistant Secretary for Fossil Energy (Acting)
Principal Deputy Assistant Secretary
U.S. Department of Energy



Christopher Smith is Principal Deputy Assistant Secretary and Acting Assistant Secretary for Fossil Energy with responsibilities for office operations and managing the oversight of Fossil Energy's Research and Development program (encompassing coal, oil and natural gas) and the U.S. Petroleum Reserves.

He was appointed to the Department of Energy in 2009 as Deputy Assistant Secretary for FE's Office of Oil and Natural Gas.

Prior to joining DOE, Smith spent eleven years with two major international oil companies focused primarily on upstream business development and LNG trading, including three years negotiating production and transportation agreements in Bogotá, Colombia.

Smith began his career as an officer in the U. S. Army and served tours in Korea and Hawaii. Smith holds a bachelor's degree in Engineering Management from the United States Military Academy at West Point and an MBA from Cambridge University.

Chairman LUMMIS. Thank you very much, Mr. Smith.
I now recognize Mr. Yamagata to present his testimony.

TESTIMONY OF MR. BEN YAMAGATA, EXECUTIVE DIRECTOR, COAL UTILIZATION RESEARCH COUNCIL

Mr. YAMAGATA. Madam Chair, Ranking Member Swalwell, Members of the Subcommittee, thank you for giving me the opportunity to make these comments today. I will specifically focus my comments on the two subject areas you asked me to address by discussing four points.First, in describing to you, as you requested, our coal technology development roadmap done in conjunction with the Electric Power Research Institute, let me say we concluded that we can develop technologies that will achieve very high conversion efficiencies moving electricity generation from today's high of 39 or 40 percent to nearly 50 percent. Following the same roadmap agenda will result in significant reductions in traditional air pollutants, leading ultimately to coal-fueled plants that really today are very clean but will be nearly emissions-free in the future. Since the 1970s, the DOE's coal R&D program and the work of the National Energy Technology Lab in collaboration with industry has, as the Assistant Secretary pointed out, now been installed on many of the coal units in this country. With DOE's support, we are confident that technology will be the pathway to also addressing CO_2 emissions from the use of coal.

Second, you have asked if our roadmap might be a way of examining the prioritization of DOE's R&D activities. Let me start by stating our general agreement with DOE's R&D portfolio and note industry's successful collaboration with the Fossil Energy Office. Where we see need for added emphasis, CCS should not be the singular focus of the government's R&D supported efforts. We recommend an emphasis also on technology development to address water use and discharge from power plants and increased support for high-temperature-materials development. These advanced materials are key to increasing the efficiency of coal conversion to electricity. DOE may need to focus more attention now on technologies that are truly transformational, and that move beyond simply adding a series of improved control technologies to power plant platforms that generate electricity from power-generating technology now itself several decades old. And finally, an inquiry should be made whether the pace of technology development pursued by DOE fits the age profile of the country's existing coal fleet. We might require commercially available technology for retrofit of coal units or the replacement of coal units by the early 2020s so that technology can be used in the later 2020s or 2030s. DOE's technology timelines could be too late by several years. Also, the President's Fiscal Year 2014 coal R&D budget request is nearly $100 million less than what we believe is required.

Third, the added cost of new and pending environmental regulations, uncertainty over future regulations and market competition from abundant natural gas have led to projections that perhaps 60 to 80 gigawatts of older coal plants—that is 20 to 25 percent of the existing fleet—will be retired in the next several years. Anticipated CO_2 requirements could dramatically increase the number of those requirements. CURC has commented that the original EPA CO_2 proposal for new coal plants requiring those plants to meet a defined CO_2 standard that can only be met with the installation of carbon capture technology that is not commercially available nor economic today, this is not a realistic standard. We will await the re-proposal of this rule, but if it is still predicated upon technology that is not commercially available, our concerns remain. Simply directing or assuming the existence of technology will not make it so.

And point four, you asked that we comment upon research activities that should be pursued in the near, mid and long term. CURC is developing a three-part program that is organized around the proposition that technology development is a positive pathway to the sustained and increased use of coal but our program is being developed through the prism of defining benefits to the Nation from coal use. In the near term, we are considering recommendations to undertake the technology R&D to address challenges to the existing baseload fleet, which is now a cycling fleet, while simultaneously confronting ever-more stringent air regulations. In the medium term, we need to ensure that the DOE demonstrations currently underway are successful. An additional demonstration program is needed to encourage the construction of world-class, coal-fueled generation plants meeting very high efficiency and emission control standards and committing those projects to retrofit with carbon capture technology when that technology is commercially available. Also, we would recommend a program to use captured CO_2 from coal-using facilities for enhanced oil recovery. We are looking for ways to accomplish our mid-term program without new government spending. Progress is being made on this front. And finally, in the long term, government in partnership with industry needs to pursue a targeted R&D program.

Thank you for your time, and I will await your questions.

[The prepared statement of Mr. Yamagata follows:]

Statement of the Coal Utilization Research Council (CURC)

Submitted to the Subcommittee on Energy

Committee on Science, Space and Technology

Hearing on

"The Future of Coal: Utilizing America's Abundant Energy Resources"

Thursday, July 25, 2013

A.1. Introduction and Summary of the CURC written statement

This statement, submitted on behalf of the Coal Utilization Research Council (CURC), addresses the findings and recommendations of the CURC-EPRI Roadmap, as well as research activities and policy considerations that will be critical to ensuring continued affordability and reliability of coal in the near, mid, and long-term.

To respond to the questions posed by the Committee this statement addresses the following:

1. **Coal is a vital domestic resource that provides low-cost and reliable electricity** - Our vast, domestically secure supply of coal has fueled the American economic machine for hundreds of years and our fleet of existing coal-fired power plants provides very inexpensive electricity. This means that U.S. industry has a competitive edge over manufacturers in other countries that do not have reliable, abundant, low-cost electricity generated from coal resources, and consumers are able to keep more of their income to spend on other expenses.

   Furthermore, as of 2012, coal continued to provide 37% of the electricity generated and consumed in this country. The Energy Information Administration (EIA) projects in its latest Annual Energy Outlook, (2013) that coal will continue to provide approximately 40% of our electricity needs through 2040 (the end of the EIA projection period). Given that the nation will continue to rely on coal, it is imperative that technologies be developed that allow for coal to be used in an increasing clean and economic manner.

   Finally, it is important to remember that diminishing or extinguishing the use of in the United States, a totally unrealistic scenario, will not address global emissions of CO_2 given the enormous growth of coal worldwide. Technology to control or prevent such emissions is the answer.

2. **But the Coal Industry Faces Several Challenges -** Coal's challenges are associated primarily with the cost of complying with an array of recent and pending Environmental Protection Agency (EPA) environmental requirements as well as competition from low cost natural gas. While existing coal-fired power plants are highly competitive with other sources of electricity, the added cost of recently adopted environmental regulations (new-source

PSD/BACT permitting), uncertainty over future regulations (recently promulgated CO_2 emissions standards for new and existing plants under Section 111 of the Clean Air Act), and other factors have led to projections that approximately 60-80 GW of older coal-fired units (20-25% of the current 310 GW coal fleet) will retire over the next several years. Furthermore, EIA projects that once 6 gigawatts of coal units now under construction commence operation (by 2015), there will be essentially no additional coal units built until after 2035, and only 1.5 gigawatts by 2040.

3. **Technology has solved coal's economic and environmental challenges in the past, and technology development and application can again solve these concerns** -- CURC's members believe that the development and application of technology to the current and future fleet of coal-fired power plants will enable our nation's coal resources to continue to contribute to the nation's generation mix while simultaneously addressing environmental and economic concerns. The proven formula for success in addressing environmental and economic concerns has been the collaborative, cost-sharing efforts of the government through the Department of Energy's Coal R&D Program and the private sector. Today, three out of every four coal plants in the U.S. are equipped with technologies that trace their origins to DOE's coal R&D program. The successful development and use of technologies have allowed coal use to increase by more than 180% since the early 1970s while the emissions rates of SO_2 and NOx have decreased by approximately 85%. In addition to developing commercial technologies to control criteria pollutants for NOx, SO2, particulate matter and mercury, the government and industry partnership is responsible for the commercial deployment of pressurized fluidized bed combustion systems, new coal-based IGCC systems, advanced turbines, and development of materials for highly efficient advanced coal combustion power plants.

   The key to ensure continued success is (1) adequate public support, (2) enhanced levels of funding targeted to specific technology areas, and (3) a regulatory and public policy framework that supports coal use.

4. **The CURC-EPRI Technology Roadmap Defines Technology Development Needs and Timelines -** CURC, together with the Electric Power Research Institute (EPRI), has developed a Technology Roadmap (Roadmap) that defines the research, development and demonstration necessary to ensure that the benefits of coal utilization in the U.S. continue into the future. The Roadmap represents a plan for developing technologies that convert coal to electricity and other useful forms of energy as well as into manufacturing feedstocks. Our Roadmap and accompanying analysis concluded that several coal technology advancements, if developed, will achieve specific cost, performance and

environmental goals thereby benefiting the nation's environment, economy, and energy security.

Importantly, the Roadmap strongly recommends that the Department of Energy continue supporting the current suite of select CCS demonstration projects and, in the future, make authorizations to encourage additional demonstrations and deployment of "second generation" and transformational coal technologies.

5. **Funding requests by the Administration must be significantly increased -** The Administration's FY 2014 recommended funding level of $276.6 million and the House's recommendation of $315.9 for Coal Research & Development at the Department of Energy is not sufficient to accomplish the important R&D necessary to support our nation's most abundant and valuable domestic resource. The reduction in federal funds will reduce private and public investments, slow development timelines, and could cause the abandonment of promising new technologies at a time when we should be aggressively supporting the development of technologies designed to overcome environmental concerns of coal use. The CURC-EPRI Roadmap recommends $372 million per year in funding for DOE's coal R&D program for fiscal years 2014 through FY 2018.

6. **A Strategic Path Forward: The CURC 3-Part Technology Plan -** CURC members have developed a technology program that aims to insure the use of coal in a cost-competitive, environmentally superior and reliable way today and well into the future (2050 and beyond). The three-part CURC technology program is designed to encourage the use of coal in the:
   - **Near-term** by applying technology solutions to the existing fleet of coal-fired electric generating plants to better insure efficiency, output, reliability and emissions-control.
   - **Mid-term** by authorizing the construction of 10 GWs of advanced coal plants that are highly efficient and superior in ability to control emissions and that will install carbon capture systems when that technology is commercially available. A second program that provides financial incentives for the capture of CO_2 to recover crude oil while directing tax receipts and royalties (not new taxes) from that recovered crude oil to pay for the CO_2 capture systems.
   - **Long-term** by focusing federal appropriations toward a RD&D program that has the goal of cost competitive, environmentally superior, and transformational uses of coal for the future.

B.1. Who is the Coal Utilization Research Council (CURC)?

The Coal Utilization Research Council (CURC) is a coalition of coal-using utilities, coal producers, equipment suppliers and manufacturers, universities and institutions of higher learning, state government entities, labor organizations as well as industry trade associations.[1] Our membership is joined together to promote the research, development, demonstration and deployment of technologies that will enable the long term use of our nation's abundant coal supplies in a cost-effective and environmentally acceptable manner. A listing of our members can be found by visiting our website at www.coal.org.

B.2 Why Coal and Coal Technology Are Important

Before addressing the technology-related questions posed by the Energy Subcommittee in the invitation to testify, it is important to underscore why coal remains so important to the Nation.

a. Coal is widely available, affordable and reliable

Continued and expanded utilization of America's vast coal resources is in the public's interest. Coal-based energy has long been the foundation of social and economic development in our country allowing more people to live better and live longer. Coal conversion to electricity, liquid fuels, or chemicals enables the United States to meet the ever-rising demand for energy. Clean coal technologies including higher efficiency generation and carbon capture, utilization and storage (CCUS) are pathways toward achieving sustainable energy, economic growth, and climate change policy goals. Further, affordable and reliable electricity driven by coal enables the expansion of electro-technologies, which are the basis of modern society.

Our vast, domestically secure supply of coal has fueled the American economic machine just as it is now fueling the phenomenal industrialization of China– as well as the economies of India, Vietnam, and other emerging economies. Lest we forget, given the almost daily news suggesting the demise of coal, this energy source provided 37% of the electricity generated and consumed in this country in 2012. And, the Energy Information Administration (EIA) projects in its latest Annual Energy Outlook, (2013) that coal will continue to provide approximately forty percent of our electricity needs through 2040 (the end of the EIA projection period). The reliance upon coal stretches well into our future as it remains an essential supplier of energy in the United States for decades to come.

Also, as we consider questions about climate change and U.S. regulatory programs CURC believes it is worth noting that if the United States simply were to abandon coal, a scenario that is unrealistic, the impact to global CO_2 emissions would be relatively small. To combat global CO_2 emissions, the U.S. must play a lead role in the development of technologies that can (and will) be deployed in China and India and elsewhere, to reduce global carbon emissions. Without technology innovation in this country, and initiatives sponsored and supported by the Department of Energy (DOE), a significant reduction in global GHG emissions is unlikely (see: Attachment A comparing China's growing use of coal to the U.S. and the rest of the world).

b. Coal-based power generation is important to the American economy

[1] Several members of CURC, including not-for-profit organizations as well as institutions of higher education, are prohibited from advocating public policy positions and therefore, to the extent this statement includes policy-related recommendations, such member organizations are not to be considered as associated with such recommendations.

Our coal-based power generation is fully dispatchable – when you need it, it is there. Other sources of electric power have their attributes, but may not be available when you need the electricity if the sun is not shining, if the wind is not blowing or if the costs of a fuel become volatile and not affordable compared to consistently stable, low-priced coal resources.

Our fleet of existing coal-fired power plants also provides relatively inexpensive electricity, and low cost power means that consumers keep more of their income to spend on other expenses. This also provides U.S. industry with a competitive edge over manufacturers in other countries that lack access to reliable, abundant, low-cost electricity generated from coal resources (see: Attachment B which depicts state-by-state cost of electricity and percent of electricity provided by coal). And, the availability of low-cost electricity is a key component to President Obama's recently announced initiative to grow manufacturing in the U.S. As a general rule of thumb, a 10% reduction in the cost of electricity leads to a 1% increase in gross domestic product and employment.[2] That equates to 1.5 million jobs. In short, our economy is greatly impacted by the price of electricity, which can be influenced by the timing and stringency of regulations to address emissions from coal.

c. Technology to capture CO_2 from coal can significantly aid energy security

While regulations are being considered to limit carbon dioxide (CO_2) emissions from power plants, it is important to keep in mind that we are developing effective technologies to capture CO_2 emissions from coal fueled facilities which can be used for the enhanced recovery of crude oil that remains trapped in reservoirs after primary and secondary production has been completed. Between 20 to 60 billion barrels of oil remain in numerous reservoirs in the U. S., not including the Bakken shale reservoirs where some estimate that only 3 to 5% of oil is currently recovered and billions of barrels of oil remain. [3] Carbon dioxide is the primary means by which this oil can be recovered. There are other sources of less costly anthropogenic (captured) CO_2 currently available, but if industry determines it is beneficial to recover the bulk of these remaining domestic oil resources, then coal-derived CO_2 is required because there are not sufficient alternative sources of CO_2 available to recover the quantities of crude oil available.[4] (See: Attachment C for additional information on estimated economic and technically recoverable crude oil potentially recoverable through the use of CO_2). A resolution to questions regarding storage where CO_2 is utilized for enhanced oil recovery must occur if the country is to reap the benefits of using captured carbon dioxide to recover crude oil. Further, while not all coal-fired power plants are near these oil reserves, many are located in close proximity to suitable oil fields. For example, in the Gulf Coast of the U.S., there is already a need for anthropogenic CO_2 to expand Enhanced Oil Recovery (EOR).

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[2] Climate Policy and Labor Markets, O. Deschenes, Working Paper 16111, National Bureau of Economic Research, June 2010, http://www.nber.org/papers/w16111 .

[3] See: http://www.eenews.net/energywire/2013/06/06/stories/1059982389 , quote by W.F. "Rick" Bott, president and chief operating officer of Continental Resources Inc., a current oil producer in the Bakken

[4] PowerPoint presentation by Phil DiPietro, NETL, Office of Strategic Energy Analysis and Planning, March 9, 2012

Several Department of Energy (DOE) demonstration projects are being developed right now that will integrate CO_2 capture technology with electricity generation and then offset part of the overall costs by selling the captured CO_2 to companies engaged in EOR.

d. Technology ensures continued use of coal which is essential for fuel diversity

Successful development of advanced coal technologies can best ensure that coal remains an option for the generation of electricity. And maintaining this diversity in fuel choice is a hedge against volatile fuel prices (e.g. natural gas prices) or potential scarcity of long-term supply of competing fuels, thereby better ensuring electricity generators can continue to provide reliable, uninterruptable and affordable electricity for American consumers. Residential, commercial and manufacturing consumers of power will reap the benefits of maintaining fuel options and for coal – technology is the pathway towards providing that insurance.

B.3. Coal's Current Challenges

All sources of energy face challenges in today's marketplace. Depending on the fuel form, the challenge may be cost of extraction or use, intermittency, infrastructure needs, or environmental impacts. In the final analysis, challenges usually boil down to increased costs. Coal's challenges are associated primarily with the cost of complying with an array of recent and pending Environmental Protection Agency (EPA) environmental requirements and market competition with currently plentiful, low cost natural gas. Additionally, the global economic slowdown has resulted in historically flat demand for additional electric generating capacity. The bulk of research associated with coal seeks to reduce sharply the cost for coal to meet future emission limitations through continued progress in coal technology development.

a. Significant coal plant retirements with modest coal builds through 2040

Existing coal-fired power plants are highly competitive with other sources of electricity, as demonstrated by the fact that coal continues to provide more electricity in the U.S. than any other fuel. However, the added cost of new and pending environmental regulations, uncertainty over future regulations, and other factors have led to projections that perhaps 60-80 GW of older coal-fired units (20-25% of the current 310 GW coal fleet) will retire over the next few years. A partial listing of recently proposed or promulgated environmental regulations affecting coal include rules limiting interstate transport of SO2 and NOx, the Mercury and Air Toxics Standards, revised New Source Performance Standards (SO2, NOx, and PM limits), the Coal Combustion Residuals rule (ash management), revised Effluent Guidelines and New Source Performance Standards for releases to water bodies, and revised Cooling Water Intake Structure rules. Climate change- related rules are discussed below.

With respect to the U.S. market for new power plants, the DOE/EIA's most recent Annual Energy Outlook projects that the overall electric power sector (including all fuels) will shrink from 1006 gigawatts of capacity in 2013 to 986 gigawatts in 2020. EIA projects that once 6 gigawatts of coal units now under construction commence operation (by 2015), there will be essentially no additional coal units built until after 2035, and only 1.5 gigawatts by 2040. These projections assume current regulations and do not reflect any future regulations limiting CO_2 emissions.

b. The regulation of carbon dioxide emissions and challenges for coal use

Most government-sponsored coal RD&D focuses on reducing the cost of systems to control CO_2 emissions.[5] Carbon is the major constituent of coal and it is the oxidation of carbon to CO_2 which produces most of the thermal energy produced when coal is burned. It is important to understand that, although additional regulations are under development, the EPA already regulates CO_2 emissions from new coal-based power plants through the Prevention of Significant Deterioration (PSD) permitting process. Each proposed new coal-based power plant must install best available control technology (BACT) for limiting CO_2 emissions as determined on a case-by-case basis by the permitting authority through the PSD process. Any available CO_2 emissions control technology or measure must be considered in setting a specific BACT limitation for the plant, although the permitting authority can eliminate those CO_2 control options that are technically infeasible or prohibitively expensive.

In addition to the current PSD regulation of CO_2 emissions from new coal-fueled power plants, two additional rulemakings are under development by EPA to set CO_2 performance standards under Section 111 of the Clean Air Act (CAA). Both rules will be governed by the statutory requirement that these performance standards must reflect *"the best system of emission reduction which (taking into account the cost of achieving such reduction and any non-air quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated."*[6]

1. The first rule will set CO_2 performance standards under Section 111(b) that directly apply to new coal-fueled power plants.
2. The second rule will establish federal emissions guildelines under Section 111(d) that will require states to set CO_2 performance standards for existing coal-fueled power plants.

With respect to the first rulemaking, EPA initially proposed in April, 2012, a CO_2 New Source Performance Standard (NSPS) for new coal-based power plants. The proposed limit was 1000 pounds of CO_2 per gross megawatt-hour of power generation, about half the emission rate for a coal-fueled unit without any add-on CO_2 emissions control technology. The rule would essentially require the use of carbon capture and sequestration (CCS) technology on any new coal-based power plant in the U.S. CURC provided comments to EPA and noted that "there is no system of controls that has been adequately demonstrated to achieve this standard for new coal fueled power plants." CURC also stated the belief that EPA's approach to apply CCS technology after a plant had been operating for 10 years was impractical for several reasons, including the inability of a plant owner to make a large capital investment in a new plant without assurance that the CCS technology needed in 10 years would be commercially available and affordable.

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[5] The CURC does not take a position for or against potential regulations or legislation addressing greenhouse gas control but if public policy is adopted to establish a control regime then it is vitally important that cost-effective technology is available to control carbon dioxide emissions from coal use.

[6] Clean Air Act, Section 111(a).

The Office of Management and Budget (OMB) is now reviewing a re-proposal of the 2012 proposed rule, and the President has directed that this new proposed rule be issued by September 20, 2013, followed by a final rule after EPA considers public comments filed on the new proposal. The President has also directed EPA to propose the second rule, for existing coal-based power plants, by June 1, 2014, and finalize that rule one year later.

CURC members have made major financial commitments to the development and demonstration of CCS technology. With time and adequate resources, we believe that industry can demonstrate that CCS is commercially available and economically viable for utility-scale applications. Although EPA was overly optimistic regarding CCS technology in its 2012 proposed performance standards, the Agency was notably unwilling to make an affirmative determination that CCS is an "adequately demonstrated" CO_2 control technology for setting a performance standard, as required by the statute. It is essential that we not overreach the capabilities of technology in setting these standards.

In addition to the technology and cost challenges facing CO_2 capture technology, challenges exist for CO_2 storage approaches, as well. There are significant unresolved "legal framework" barriers to CO_2 storage in saline formations, including exposure to significant liabilities and risks for scores of decades after closure of the power plant. The good news is that, assuming these barriers are adequately addressed, the North American continent has promising storage sites for thousands of years of CO_2 emissions from electric power generation.[7] Again, not all power plants are located in close proximity to potential CO_2 use in EOR applications and because the source of CO_2 (i.e. power plant) is not in close proximity to any EOR field then storage in saline formations could be the only option. This means that these legal framework barriers must be addressed concurrent with the development of CO_2 capture technologies.

B.4. Track Record on Technology: Solving Challenges with Technology

Congress should be confident that challenges to the use of coal, most specifically those related to the control or capture of CO_2 from coal use, can be addressed through the successful development and use of technology. We are not there yet; significant time and financial support are required, along with a realistic understanding that simply directing or assuming the existence of technology will not make it so.

Since the early 1970s, the DOE Coal RD&D program and DOE's National Energy Technology Laboratory (NETL) have been responsible for developing innovative technologies for coal-fired power plants such as low nitrogen oxide (NOx) burners, Selective Catalytic Reduction (SCR), flue gas desulfurization (scrubbers), and fluidized bed combustion, all of which are now in the marketplace and benefitting energy production and air quality improvements.[8] In fact, today, three out of every four coal-burning power plants in the U.S. are equipped with technologies that can trace their roots back to DOE's advanced coal technology program.

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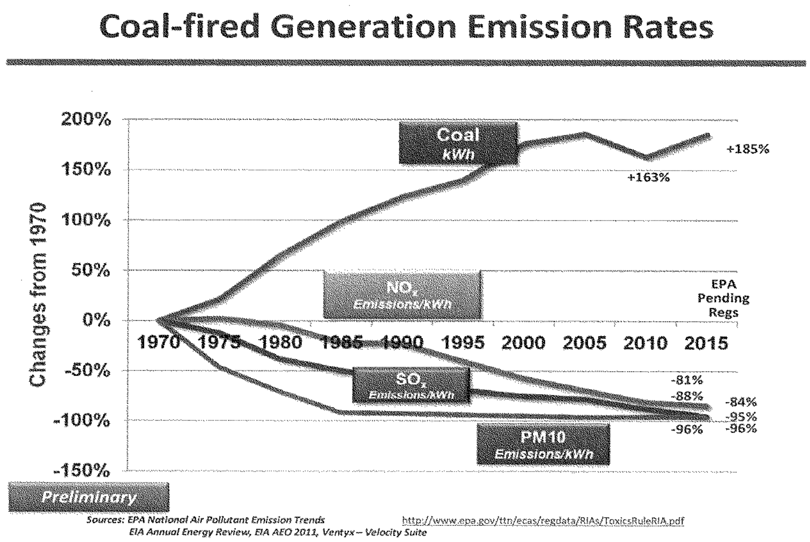
[7] The DOE/NETL atlas of geology favorable to CO_2 storage has identified deep underground saline geologies which could accommodate 2 – 20 trillion tonnes of CO_2. This range is enough to store the CO_2 from the entire U.S. coal-fueled fleet operating for 1,000 to 10,000 years.

[8] http://energy.gov/sites/prod/files/roi_factcard.pdf

The benefits from federal investment in these technologies is evidenced by the fact that coal use in this country has increased by more than 180% while the rate of emissions of criteria pollutants, such as SO_2 and NOx, has decreased by an average of 85% since enactment of the CAA in the early 1970s.



Furthermore, DOE estimates that the public and private sector RD&D collaborations through the Department's clean coal technology programs have provided great value to the taxpayer yielding a return of $13 for every dollar of federal funding spent for coal RD&D between 2000 and 2020.[9] Reducing the cost of mercury control by 50-70% helped save the industry $4 billion to $5 billion annually in implementation costs, and NETL in coordination with the private sector was responsible for the development and deployment of this technology.[10]

DOE, through NETL and its coal RD&D programs, together with cost-sharing from industry, have demonstrated that technology research, development, demonstration and deployment can be used to significantly reduce emissions from coal-fired power plants. And just as technology has been used in the past to address environmental challenges associated with coal use, we can develop technology again to address CO_2 emissions and further reduce traditional pollutant emissions, if given sufficient time and sustained government support for technology development.

[9] Ibid.
[10] Ibid.

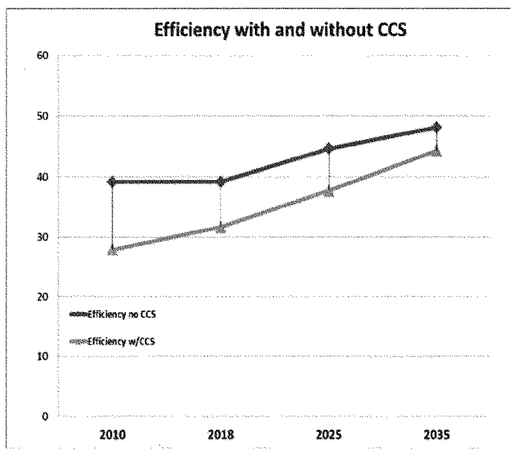
B.5. CURC/EPRI Roadmap

CURC, together with the Electric Power Research Institute (EPRI), have developed a Technology Roadmap (Roadmap) that defines the research, development and demonstration necessary to ensure that the benefits of coal utilization in the U.S. continue into the future. The Roadmap represents a plan for developing technologies that convert coal to electricity and other useful forms of energy as well as into manufacturing feedstocks. Our Roadmap and accompanying analysis concluded that several coal technology advancements, if developed, will achieve specific cost, performance and environmental goals thereby benefiting the nation's environment, economy, and energy security.

An earlier CURC/EPRI Technology Roadmap was published by CURC and EPRI in 2008. The CURC membership began updating the 2008 Roadmap in 2011 and finalized the updated Roadmap in the summer of 2012. This updated Roadmap includes new data on recent advances in technology; addresses the increased stress on the U.S. economy which has diminished our ability to support technology development; accounts for the increased supplies of natural gas; and recognized the uncertainty of policies with respect to controlling emissions of CO_2.

a. Technology Benefits

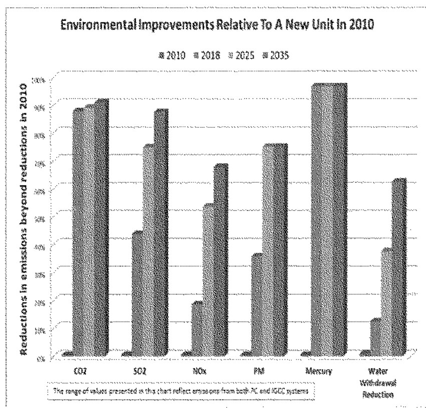
Improvements in power plant efficiency with successful R&D



One of the most significant benefits from the proposed technology improvements identified in the Roadmap is the increase in efficiency of power generation. This improvement in efficiency reduces all emissions, including CO_2, due to less fuel being required for a given amount of electrical generation. Improvements in overall power plant efficiency for combustion-based systems as well as significant cost reductions in gasifiers and improved gas turbines are projected to result in a levelized cost of electricity (LCOE) for these advanced coal fueled systems with CCS that is lower than today's coal-fueled power plants without CCS .

Other additional benefits of successfully implementing the Roadmap include (1) aggressive reduction of water use/discharge, (2) significant reductions in traditional air pollutants and CO_2, (3) enhanced energy and economic security via production of low cost power using coal, our largest U.S. domestic energy resource while using captured CO_2 to recover crude oil, and (4) deploying coal-based technologies for the production of liquid fuels and other marketable products.

Improvements in the control of conventional pollutants and water conservation



2010 "State of the Art" Baseline Data

Reductions reflect a range of values for both PC and IGCC technology changes after 2010, but the reductions in 2010 are very significant:

CO_2: 0% (no carbon controls in use)
NOx and SO_2: 90 - 99% reduction
PM: 99.6% reduction
Mercury: 90% reduction
Water Withdrawal Reduction (as a result of cooling towers): 98%

b. The Importance of on-going demonstrations

First, the Roadmap requires that the current suite of "first-generation" CCUS demonstration projects are fully launched and successfully operated. These projects, which are currently underway or in the planning process, are receiving or have received funding from industry and the federal government through demonstration grants (the Clean Coal Power Initiative (CCPI) or the Industrial Carbon Capture and Storage (ICCS) program) or other financial incentives (§§48A & B tax credits). It is important to note that power generation equipped with CCUS technology is not yet affordable. In fact, a number of projects selected for demonstration by the DOE through the variety of cost-share or financial incentive programs have since been cancelled. Project sponsors have concluded, even with substantial government-offered support, that continuation was not economic.

c. The need for additional demonstrations – ultrasupercritical and CO_2 for EOR

Concurrent with the need for successful demonstrations of first generation projects, it is highly important that subsequent demonstrations be undertaken. Given the prospect that the market alone will not be sufficient to undertake additional demonstrations of the technologies currently undergoing planning and construction, CURC strongly recommends that authorizations be made to encourage additional demonstrations and deployment of technology at or near commercial scale. That is the reason for our recommended mid-term program of additional demonstrations (see discussion below). Without this continued activity during a period when little, if any, new coal-fueled power plants are projected to be built, we would lose momentum in maturing the technologies under demonstration. Further, without the prospects of additional commercialization and use, expertise and know-how will rapidly dissipate and infrastructure and even physical resources (sufficient coal resources and capacity to construct) will disappear with significant uncertainty as to whether these resources can be reconstituted.

d. Increased and targeted funding for coal-based technology R&D

This exact same need for financial and policy support for coal technology development exists with respect to continued, robust funding for the government's RD&D programs, particularly those administered by the DOE's Fossil Energy Office and conducted through NETL. That laboratory is focused upon supporting continued improvements in the development of the next generation of coal fueled technologies. These "second generation" technologies as well as "transformational" technologies, according to the conclusions reached in our Roadmap, will be deployed in the 2025 and 2035 timeframe, respectively. These future technologies have the greatest promise toward reducing the cost of CO_2 capture. As the Roadmap suggests, in 2030, if a power facility was reasonably close to an EOR opportunity, the CO_2 could become a valued commodity. In this instance, the levelized cost of electricity (LCOE), assuming we are successful in developing advanced power plants equipped with CO_2 capture(as described in the Roadmap), and selling the CO_2 for EOR, could be decreased significantly to a value of approximately $65/MWh, which is competitive with other low cost sources of electricity.

One important program being supported by the DOE program is the work being done at the National Carbon Capture Center (NCCC) which is successfully identifying and developing new and novel CO_2 capture concepts. Several hundred CO_2 capture possibilities have been catalogued at the NCCC that need to be screened, and where promise exists, NCCC demonstrations conducted. Because of on-going research efforts at this research facility and elsewhere, the earlier prospect of a 35% parasitic penalty (the amount of electricity from the power plant needed to operate the carbon capture system) is now much closer to 20%, with many opportunities to drive this energy penalty even lower.

Another key Roadmap recommendation is a "carbon storage site certification" program to characterize and qualify 5 regionally-diverse sites that can each accept 50 million tons of CO_2 at a rate of 5 million tons per year. Such a program would accelerate the demonstration of permanent CO_2 storage in saline formations and prove out the stability and safety of this method of CO_2 sequestration.

e. *Limited government and industry resources requires carefully selected areas for support*

We must focus efforts on evaluating, estimating and developing technologies that capture CO_2 affordably. The best, most reliable and efficient technology, if not affordable, will not sustain coal's continued use.

To assure affordability from the end-user's perspective, we must not ignore what the DOE and industry can afford. Restricted budgets are a reality and the Roadmap was developed with the intent of providing guidance as to how limited public funding might be used to maximize the future cost benefits of technology development. This is likely going to involve tough decisions so that the available funding is spent wisely on technologies that have the highest potential for successful widespread commercialization.

f. *Specific Areas of divergence from the FY 2014 budget request*

CURC fully supports the Administration's requests in its FY 2014 budget to continue development of cost-effective technology to capture and use or store CO_2. However, we also believe the FY 2014 Coal R&D budget may be too singularly focused on the development of CCS. There are several other areas of critical technology development that require attention and support.

For example, given the changing nature of the power generation sector and the role of other sources of electricity generation, the program should also focus on technology needs applicable to both the existing and new fleet of coal power plants by addressing improved efficiency, reliability, and flexibility in generation. The program currently lacks any emphasis on needs relevant to the existing fleet except for CO_2 capture.

Other examples of programs that are included in the CURC-EPRI Roadmap but not reflected in the Administration's proposed FY 2014 budget, include a water management program. Such a program should be designed to model water use for a variety of coal technologies as well as to develop technologies to reduce water withdrawal and consumption at power generation facilities.

Given the age of the current power generation fleet in the U.S., there exists a very significant challenge that RD&D be conducted in a timely fashion. Power plant units are aging and by the time many of these technologies are ready for commercial use, the existing coal units may simply be too old for retrofitting new technology or will be candidates for retirement. We must examine the pace of technology development and the ability to apply CCS on these units. We believe that a portion of the existing fleet will be candidates for successfully commercialized CCS technology, but that technology development cannot be postponed or delayed for lack of financial support from the government and industry. Stretching out development time due to lack of funding is not advisable. In this same regard we are concerned that many existing coal units could be retired before DOE is projecting completion of RD&D on transformational technologies such as chemical looping or pressurized oxy combustion and this existing coal fired generating capacity will be replaced with potentially more expensive non-coal fired technologies. If successfully developed in time, these transformational coal fired technologies could be realistic candidates for new power plant applications to replace retiring units. It is therefore very important that there be a serious evaluation of whether DOE's technology portfolio needs to be substantially accelerated to meet real world needs and future opportunities to deploy the next generation of coal-fueled generating units.

Finally, as noted in the CURC/EPRI Roadmap, the DOE program also should support "breakthroughs" in technology R&D across several program areas that encourage revolutionary approaches to converting coal to useful energy and products. Importantly, the emphasis of this initiative is a focus on new ways to use coal rather than a primary focus on the capture and use, or disposition of CO_2 from coal fired plants. An example of a breakthrough technology might include the substitution of biosystems for current chemical processes. An example of such breakthrough technology might be a genetically engineered microbe that could be used to convert coal to methane or hydrogen, eliminating many sources of pollution and creating a physically more convenient form of energy (see: Attachment D for a depiction of the timelines for technology development in the CURC-EPRI Roadmap).

B.6. Budget Requirements and Implications

Government partnership support and funding commitments are critical to ensure that the goals of the Roadmap are accomplished. In order to achieve the objectives of the Roadmap funding ranging from approximately $465 million per year through 2018, $363 million per year through 2025, and then $189 million per year after 2025 is required. Of this amount, the Roadmap recommends continuation of the current R&D policy of 80% federal and 20% private or other funding for research and development activities. Accordingly, in FY 2014 through FY 2018, the coal R&D program would require $372 million per year in funding from the DOE's coal R&D program. This amount is contrasted to the $316 million that the House recently recommended in coal energy R&D for FY 2014 and the $276 million requested by the Obama Administration for FY 2014.

In summary, the Administration's FY 2014 recommended funding level of $276.6 million and the House's recommendation of $315.9 for Coal Research & Development at the Department of Energy is not sufficient to accomplish the important R&D necessary to support our nation's most abundant and valuable domestic resource.

Congress, and particularly the House of Representatives, over the course of the last several appropriations cycles has recognized the need for additional funding and we would urge such additions in the FY 2014 budget, as well (See: Attachment E for a tabular history of appropriation requests and approved levels of funding for the DOE coal R&D program).

Also, as set forth in the Roadmap, an additional effort will be needed to construct and operate commercial scale projects to demonstrate the best of these R&D products. That demonstration program has an estimated capital cost of about $6.2 billion for demonstration units built through 2025, and another $3.5 billion for demonstrations built between 2026 and 2035. None of this funding for commercial-scale technology demonstrations is currently contemplated through existing federal budgets.

B.7. Strategic Steps Forward

It is useful to step back from the detail of the CURC-EPRI Roadmap and consider coal technology development activities which could accelerate progress in meeting coal's challenges, and ensure that the country continues to enjoy, if not expand, the benefits of using coal. CURC has undertaken such an examination and is recommending that a 3-part program be considered that consists of discrete activities targeted at the (1) near-term, (2) the mid-term, and (3) the long-term.

a. The near-term program

In the near-term, CURC believes that the key area to address is the existing coal fleet. Given the recent EPA regulations, the expanding need for flexible operation on electricity networks increasingly populated with intermittent renewable electricity generation, and the age profile of the existing coal fleet, it is important to examine existing technologies, including a determination as to whether short-term R&D aimed at compliance and improved efficiency, reliability, and flexible operation would be helpful. In suggesting this effort, CURC recognizes that a major challenge when targeting research for the existing fleet is that R&D on power systems takes time, and the time necessary to develop new compliance options can be greater than the time allowed in regulations to bring sources into compliance.

b. The mid-term program

For the mid-term, CURC recommends two programs be simultaneously undertaken. The first would take advantage of the fact that new CO_2-EOR activities enable oil production, and lead to tax revenues from profits on that oil production which would not happen absent the availability of CO_2. CURC has under consideration a proposal that would operate to provide that a portion of the new tax revenues be used to partially offset the CO_2 capture cost at coal-based power systems linked to EOR. Such a program could enable increased domestic oil production, speed CCS technology development, and provide competitively priced electricity, without increasing tax rates for individuals or industry. Success in this limited program could lead to a greatly expanded national CO_2-EOR program which would function without government assistance – creating a significant number of new jobs, improving the U.S. trade balance, and reducing foreign oil imports.

The second mid-term initiative would deploy high-efficiency coal-based power generation without waiting until complementary CCS systems can reach economic viability. This program, limited to 10 gigawatts of new generation capacity commencing service in the 2020s, would apply only to units which agree to deploy the most efficient plant designs and meet specific environmental performance criteria, with the exception of CO_2. For reducing CO_2 beyond the capability of high-efficiency operation, the plant owners would agree to install CCS technology within a designated period of time after the Secretary of Energy determines that the technology meets an affordability cost criterion, such as a certain \$ per megawatt-hour or \$ per tonne CO_2 limit.

c. The longer-term program

CURC's longer term activity encompasses the bulk of the CURC-EPRI Roadmap, which must be immediately implemented in order to ensure the technologies are available in the 2025-2030 timeframe contemplated in the Roadmap. We would highlight CURC's proposal for "qualifying" several regionally diverse CO_2 saline storage formations to ease the challenge for early adopters of CCS technologies; the National Carbon Capture Center as a means to test new capture concepts without the need for time consuming and cost redundant resources for simulating a power plant environment; the need for truly transformational new technologies to minimize the cost of power from coal units with CCS; and the need to expand NETL's scope to consider traditional air and water pollutants, power plant cooling systems, and technologies to improve power plant efficiency.

C. Conclusions

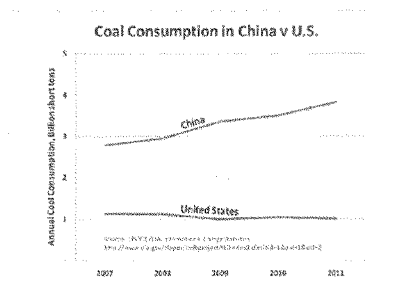
CURC wishes to thank the Committee for the opportunity to provide this statement.

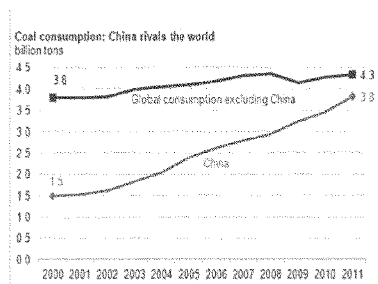
The development and then application of technology has been a key factor to the sustained use of U.S. coal resources. Advanced coal-based technologies, including CCS technologies, if given sufficient time, encouragement and sustained public support will be developed just as technologies for coal have been developed in the past. Thus, any clean energy future for this country can, and should, encompass one of the Nation's most abundant, domestic resources -- coal.

It may be worth reminding ourselves, while we encounter the musings of coal's demise that coal can point to many decades of supporting the Nation's economy, and 40 years of R&D successes in addressing environmental issues. We have cashed the dividends of coal technology investments made by our fathers, and this Committee has the opportunity to make that statement true for our children as well.

Attachment A

Coal Dominates China's Energy Supply

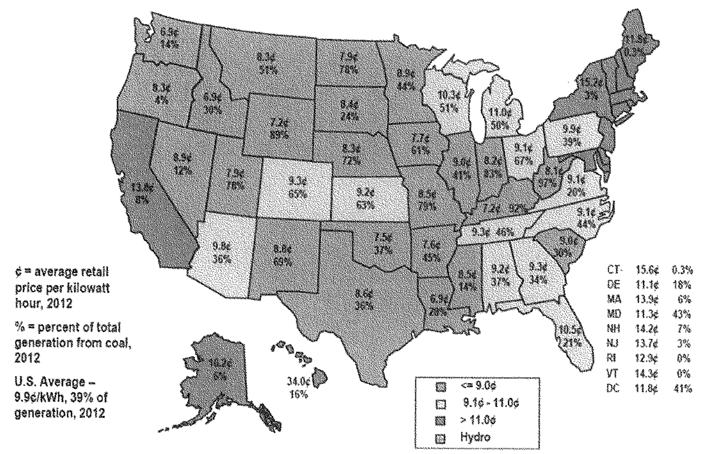




- China accounts for 47% of global coal consumption, almost as much as the rest of the world combined
- In 2011, coal consumption in China grew >9% for the 12th year of an upward trend
- China has 700 GW of installed coal capacity, compared to only 310 GW in U.S.

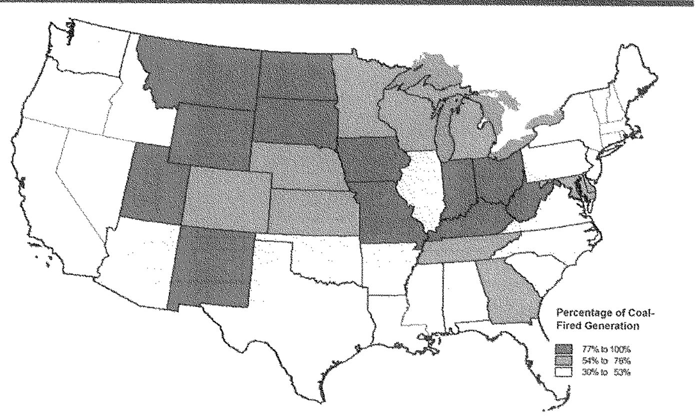
Attachment B

Cost Per kWh & Percent of Coal Power Sector Generation



Sources: Energy Information Administration, *Electric Power Monthly*, March 2013 (2012 data); Public Service Commission of the District of Columbia (2012); California Energy Commission (2011 latest available); Washington State Department of Commerce (2011 latest available). 2012 data are preliminary.

State Coal-Fired Generation Intensity



33 or 50 States produce 30% or more electricity from coal-fired generation

Attachment C

There is a lot of EOR

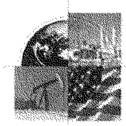
Table 7. Economically Recoverable Resources from Applying "State-of-the-Art" CO2-EOR: National Totals at Base Case Economics*

Basin/Area	Incremental Technically Recoverable (Billion Barrels)	Incremental Economically Recoverable* (Billion Barrels)
1. Alaska	12.4	9.5
2. California	6.3	5.4
3. Gulf Coast (AL, FL, MS, LA)	7.0	2.2
4. Mid-Continent (OK, AR, KS, NE)	10.6	5.6
5. Illinois/Michigan	1.2	0.5
6. Permian (W TX, NM)	15.9	7.1
7. Rockies (CO,UT,WY)	3.9	1.9
8. Texas, East/Central	17.6	8.3
9. Williston (MT, ND, SD)	2.5	0.5
10. Louisiana Offshore	5.8	3.9
11. Appalachia (WV, OH, KY, PA)	1.6	0.1
Total	**84.8**	**45.0**

*Base Case Economics use an oil price of $70 per barrel (constant, real) and a CO2 cost of $45 per metric ton ($2.38/Mcf) delivered at pressure to the field.

Storing CO2 with Enhanced Oil Recovery

DOE/NETL-402/1312/02-07-08



February 7, 2008

NETL

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The EOR CO2 demand greatly exceeds natural (cheap) CO2 supply

Table 13. Economically Feasible Market Demand for CO2 by EOR: NEMS/EMM Power Generation Regions*

NEMS EMM Region	Purchased CO2 Requirements	Natural CO2**	Industrial CO2**		Unmet (Net) Demand for CO2	
	(Tcf)	(Tcf)	(MMcfd)	(Tcf)	(Tcf)	(Million mt)
Region 1 - ECAR	1.1	-	15	***	1.1	58
Region 2 – ERCOT	72.2	25	110	1.2	46.0	2,436
Region 3 – PJM (MAAC)	0.1	-	-	-	0.1	4
Region 4 – MAIN	1.9	-	-	-	1.9	100
Region 5 – MAPP	2.1	-	-	-	2.1	109
Region 6 – NY ISO	-	-	-	-	-	-
Region 7 – NW ISO	-	-	-	-	-	-
Region 8 – Florida	0.2	-	-	-	0.2	9
Region 9 – SERC	40.0	8	-	-	32.0	1,695
Region 10 – SWPP	29.7	5	35	0.4	24.3	1,286
Region 11 – WECC/NWPP	7.8	-	175	1.9	5.9	311
Region 12 – WECC/RMPP	2.3	-	65	0.7	1.6	83
Region 13 – WECC/CA	26.0	-	-	-	26.0	1,377
Region 14 - Alaska	39.6	5	-	-	34.6	1,831
TOTAL U.S.	223.0	43	400	4.2	175.8	9,301
~~TOTAL Lower-48~~	~~183.4~~	38	400	4.2	141.2	7,470

*Base Case: $70/Bbl oil and $45/mt CO2
**Assumed available to be produced and productively used by the CO2-EOR industry in the next 30 years.
***Less than 0.01 Tcf and thus not included in totals.

That's about 40,000 MW of coal generation for 30 years.

Bottom line: We need another 7.5 B tonnes of CO2 for EOR.

Key Assumption.

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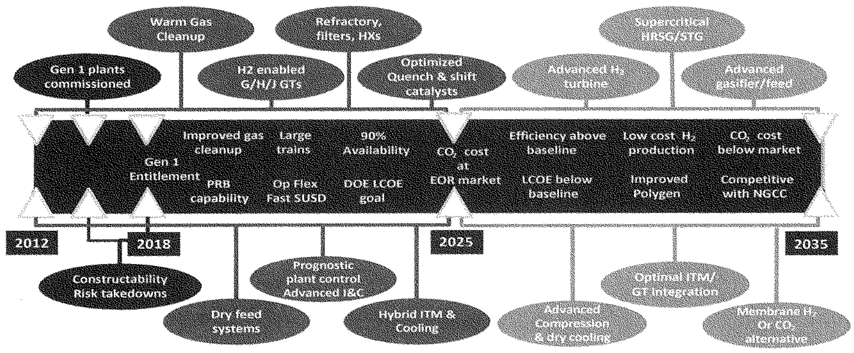
Attachment D

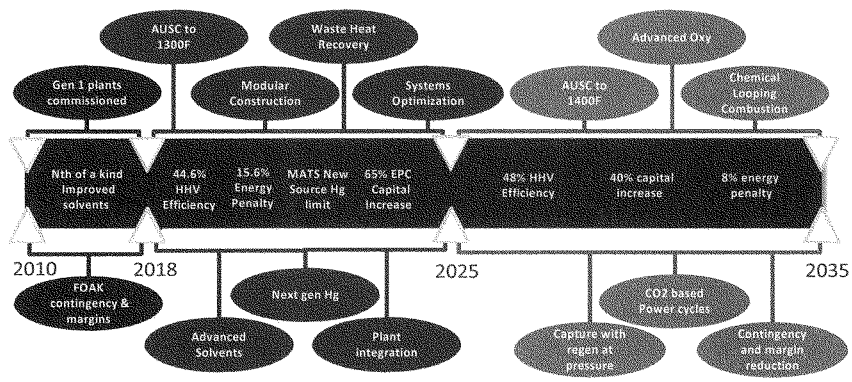
Gasification-related technologies

Gasification Timeline and Impact



Key Combustion-related technologies

Combustion Timeline and Impact



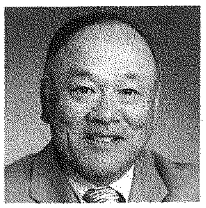
Attachment E

HISTORY OF APPROPRIATIONS REQUESTS AND ENACTED AMOUNTS

DOE CCS & Power Systems Budget ($$ in Thousands)	FY 2008 Request	FY 2008 Omnibus	FY 2009 Request	FY 2009 Omnibus	FY 2010 Request	FY 2010 Enacted	FY 2011 Request	FY 2011 Enacted	FY 2012 Request	FY 2012 Enacted	FY 2013 Request	FY 2013 CR
Coal R&D Program TOTAL	426.5	493.5	623.7	692.4	403.9	404	403.9	390	291.3	360	275.9	370

DOE CCS & Power Systems Budget *($$ in Thousands)*	FY 2014 President's Request	FY 2014 House	FY 2014 Senate	FY 2014 CURC Roadmap
Coal R&D Program TOTAL	276	315	268	404

VanNess Feldman



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Practice Areas
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Environment, Natural Resources, & Public Lands
Government Relations & Public Policy

Education
J.D., George Washington University National Law Center, 1972
B.A., Harvard College, 1969

Bar and Court Admissions
District of Columbia

Ben Yamagata
Partner

Ben Yamagata's practice encompasses federal and state legislative and administrative issues in the areas of energy, environment, natural resources, international trade (technology transfer and independent power project development), and transportation-related matters.

Mr. Yamagata represents clients before the Departments of Energy, Commerce, Transportation, Defense and State, as well as the Office of Management and Budget and the Environmental Protection Agency, on both project-specific and programmatic issues that relate particularly to technology research, development, demonstration, and deployment relating to the use of coal and other fossil and renewable energy resources. Mr. Yamagata has advised clients on energy and environmental technology projects as well as provided counsel and representation in the structuring and advocacy for government programs such as the Department of Energy's clean coal technology development and demonstration programs and financial incentive programs (*e.g.*, loan guarantees and clean coal tax credits) that were authorized as part of the Energy Policy Act of 2005.

Mr. Yamagata serves as the Executive Director of the Coal Utilization Research Council (CURC), a coalition of industry and educational institutions with an interest in promoting clean coal technology.

Government Service

U.S. Senate

- Counsel/Staff Director, Subcommittee on Energy Research and Development, Committee on Energy and Natural Resources, 1975-1977
- Legislative Counsel, Senator Frank Church (D-ID), 1974-1975
- Professional Staff Member, Special Committee on Aging, 1972-1974

Chairman LUMMIS. Thank you, Mr. Yamagata.
I now recognize Mr. Collins for five minutes.

TESTIMONY OF MR. DON COLLINS, CHIEF EXECUTIVE OFFICER, WESTERN RESEARCH INSTITUTE

Mr. COLLINS. Good morning, Chairman Lummis, Ranking Member Swalwell and Members of the Subcommittee. I am Don Collins from the Western Research Institute located in Laramie, Wyoming. On behalf of everyone at WRI, we deeply appreciate the opportunity to provide testimony on the vital role of innovative scientific research and technology development that can assure a diverse energy resource portfolio that utilizes our Nation's abundant coal resources efficiently and environmentally responsibly.

WRI is a multidisciplinary scientific research and technology development nonprofit institute currently specializing in bioenergy, natural gas, emission capture, environmental monitoring and remediation, asphalt chemistry, heavy and ultra-heavy oils such as Canadian oil sands, as well as clean coal power, gasification and conversion to transportation fuels, hydrogen and industrial chemicals. So I will summarize my testimony and request that my testimony be entered into the record.

Our view is that R&D work is successful when viable technologies are deployed to the betterment of our country. So in my written testimony, I highlight opportunities to utilize carbon to achieve energy recycling for living in a carbon-rich world: utilize low-rank coal as an untapped water-rich resource, increase plant efficiencies to lower emissions of hazardous air pollutants and lower water consumption, leverage existing coal power plant investments to also clean up eco-legacy contamination levels such as for mercury, create a diversified energy technology portfolio to best serve very local conditions, and resource availability across the United States.

Based on WRI's experience and expertise, I recommend that Congress take some of the following actions: consider policies that allow exploring solutions for living in a carbon-rich world in addition to living in a carbon-constrained world; cultivate a national best portfolio strategy to leverage all energy resources and utilization technologies; formulate a flexible, integrated clean energy technology research portfolio and priorities that consider local and regional constraints; allocate funding to support the utilization of carbon dioxide to stimulate the transformation of this abundant compound from something to be avoided to a beneficial resource that can be used to increase chemical feedstocks, biofuels and support national energy self-sufficiency; allocate resources for research to support the sustainable and environmental safe use of fossil fuels, especially energy and water efficiency advancements in connection with the energy-water nexus; formulate a Federal leadership team to strategically plan advanced energy and water efficiency improvements and environmental impact reductions across the entire coal sector.

In summary, at WRI, we take a portfolio approach to provide sustainable energy solutions. Our thinking approach will deliver cost efficiencies and environmental benefits with respect to utilization of coal. The many boom-and-bust cycles that we have experienced in the energy sector really are a function of the marketplace, but the way in which we can minimize the downside of this fact of life is through an aggressive, innovative partnership between industry, research entities and the Federal and state governments. This will ensure our energy technology portfolio will deliver benefits to the U.S. consumers and protect the environment.

I would note, for example, that the State of Wyoming is implemented a long-term strategic plan to maximize the entire energy portfolio within Wyoming, utilizing CO_2 for enhanced oil recovery and preparing for long-term storage of CO_2. These are precisely the kind of activities the Federal Government should encourage. Making the best use of limited financial investments in addition to efficient utilization of all energy resources is key to achieving national sustainability goals, energy security and economic prosperity.

In closing, a strong commitment to a portfolio approach that includes solutions for living in a carbon-rich world will facilitate innovation and sustainable economic growth that in turn strengthens U.S. competitiveness. This necessitates continued Federal funding of scientific research and technological development. It is essential to maximize the energy efficiency and productivity of our country in the most environmentally and economically sustainable ways.

Again, I thank you for the opportunity to appear before you, and I would be pleased to answer any questions the Subcommittee may have.

[The prepared statement of Mr. Collins follows:]

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TESTIMONY

Donald W. Collins, Jr.
Chief Executive Officer
Western Research Institute
Laramie, Wyoming

Submitted To The
Honorable Cynthia Lummis
Chairman

Subcommittee on Energy
Committee on Science, Space And Technology
U.S. House Of Representatives
Washington, D.C.

Hearing On The Future Of Coal:
Utilizing America's Abundant Energy Resources

July 25, 2013

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Chairman Lummis, Ranking Member Swalwell and members of the Subcommittee I am Donald Collins, CEO of the Western Research Institute located in Laramie, Wyoming on the campus of the University of Wyoming. On behalf of WRI, we deeply appreciate the opportunity to provide testimony on the vital role that coal research and development activities can play to ensure a diverse energy resource portfolio that relies on our abundant coal resources. WRI has dedicated its extensive capabilities and experience to drive our use of coal in technologically efficient, environmentally responsible and cost effective manner.

INTRODUCTION

As a matter of background, WRI employs a team of 83 scientists, engineers, technicians and management professionals working on both basic and applied research, development, and technology demonstration and deployment (RDD&D). Our scientists for the past four decades have developed solutions and technologies to advance energy exploration, recovery and utilization. We also have used our expertise in the energy sector to address the needs of the public and private sectors in the fields of environmental remediation, ecosystem protection and public safety. I provide additional information on WRI and our work as background and overview about WRI is provided in Attachment A.

COAL RESEARCH ACTIVITIES

At Western Research Institute (WRI), we are focusing our coal utilization research and technology development activities to enhance the sustainability of coal through improvements in (1) utilization and energy efficiency, (2) environmental cleanliness and (3) sustainability. Below are brief paragraphs about each.

Enhancing Coal Utilization Energy Efficiency – Several process technologies were devised to increase the energy efficiency of coal power plants while also lowering criteria pollution emissions.

Enhancing Coal Environmental Cleanliness – An added benefit to enhancing coal utilization energy efficiency is the ability to address criteria pollution emissions, including carbon dioxide (CO_2). This is accomplished by lowering such pollutant emissions per megawatt hour (MWhr) delivered to the grid. WRI recognizes that knowledge has evolved regarding environmental and health ramifications associated with human activities of all types, including extraction and utilization of energy resources. We view this knowledge as valuable and help us develop appropriate priorities for research and technology development and more importantly deployed. This ensures development of a portfolio of cost-effective and sustainable technology solutions.

Enhancing Coal's Sustainability – The challenge for coal from a sustainability perspective is that coal resources removed carbon dioxide from the atmosphere hundreds of millions of year ago when the naturally occurring processes of that era resulted in the creation of coal from biomass. This ancient age of coal relative to conventional biomass energy systems presents a great challenge to any notion that coal can contribute to sustainability within the much shorter time spans considered appropriate for sustainable clean energy models.

To tackle this timing challenge of energy system CO_2 recycle ability and to achieve sustainable energy systems, WRI is focused on the opportunity to invent ways to recycle all carbonaceous forms of energy to include coal. To date, humans have devised solutions to recycle many products such a paper, plastic, metals, batteries, etc. to extract and reuse the materials and in turn achieve economic and environmental benefits. Now via biological sciences applied to our fossil energy resources we are at the forefront of achieving the capacity to recycle carbonaceous energy.

At their core biomass, coal, petroleum, and natural gas are energy resources that contain two primary energy carriers – carbon and hydrogen. By conventional wisdom, burning wood is viewed as "carbon neutral" from a sustainability perspective based upon the amount of CO_2 emitted through burning equaling the amount of CO_2 trees took from the atmosphere to grow. This leads to the conventional view that burning wood is a sustainable carbon neutral energy system[1] that does not result in a net increase in atmospheric levels of CO_2 (a greenhouse gas) as does the combustion of traditional fossil fuels such as coal and natural gas. From a sustainability systems view, burning coal yields a net increase in atmospheric CO_2 inventory is ultimately a timing and rate/speed issue due to the fact the original biomass, from which coal is created, is about 300 millions old and trees living today do not consume atmospheric CO_2 at a rate fast enough to recycle the amount of CO_2 produced from burning coal, natural gas, and petroleum transportation fuels.

WRI is conducting research to quicken the conversion of CO_2 emissions from coal, natural gas and cement plants into a more timely useable form of energy – biological crude oil (biocrude). Our primary research activity involves developing two biotechnology related

[1] The Partnership for Policy Integrity (PFPI) life cycle analysis work challenges the notion that burning wood in commercial and utility scale energy plants is a carbon neutral sustainable energy system. In a review of the Manomet Biomass Sustainability and Carbon Policy Study performed for the Clean Air Task Force comparing carbon emissions between biomass and fossil fuel power plants, PFPI concluded, "**For utility-scale generation, net emissions are higher from biomass than fossil fuels.** When biomass is used to generate electricity in utility-scale plants, the net emissions after 40 years, even taking forest regrowth into consideration, are still higher than if the power had been generated with natural gas or coal." In discussing the Manomet study assumptions, PFPI stated, "To the extent that these assumptions are not warranted, the Manmet study has underestimated the net carbon emissions of biomass power, and policy-makers should be extremely cautious about accepting the study's optimistic conclusions concerning the point in time when biomass can start providing a carbon dividend."

processes to capture and convert CO_2 using chemoautotrophic (CAT™) bacteria. CAT™ bacteria continuously consume CO_2 without requiring light. Bench-scale research results are extremely promising, and system-level modeling and simulation estimate synthetic diesel production costs a \$3 to \$5/gallon. By changing our mindset away from conventional thinking in which CO_2 is viewed solely as a threat to our planet and human life we were able to explore ideas to utilize CO_2 that provide societal and economic value.

Our endeavor was to devise a technological solution that consumed significantly less energy and financial resources compared to carbon capture and underground sequestration (CCS). We also discovered that it would be possible to produce chemical feedstock to provide an alternative to petrochemicals that can help meet growth in global consumption. Our aim is to avoid expenditure of valuable energy and limited financial resources for underground CCS for which no additional societal benefits beyond containing atmospheric CO_2 inventory levels are achieved. Applying the WRI CAT™ Process as a CO_2 recycle accelerator we see the potential to achieve the goal of anthropogenic CO_2 emission reduction via a societal integrated and economically sustainable systems approach.

Our preliminary assessment of net societal/national CO_2 emission reduction is based primarily upon the integration opportunity for two existing large societal sector CO_2 emitters: (1) the power sector and (2) the transportation sector. Applied to the power sector, the CAT™ process can reduce CO_2 power plant emissions which are then converted into a synthetic diesel fuel for the transportation sector. The integrated societal energy system CO_2 reduction results when the synthetic diesel is used to displace conventional diesel consumption – achieving a second use of the carbon within coal prior to the eventual CO_2 emission from vehicle exhaust pipes. While the transportation sector CO_2 emissions are not directly reduced, the fact that the CAT™ biodiesel fuel prevented power plant CO_2 emission from entering the atmosphere we achieve an integrated societal system reduction in CO_2. A descriptive formula comparison of Today (without CAT™) and a Future (with CAT™) illustrates the how an integrated societal energy system achieves lower net CO_2 emissions:

Today's Total CO_2 (without CAT™) = Power Sector CO_2 + Transportation Sector CO_2 + Other CO_2 Emitters

Future Total CO_2 (with CAT™) = Power Sector CO_2 <u>lowered by 80% to 90%</u> + Transportation Sector CO_2 + Other CO_2 Emitters

A calculation performed in 2011 based upon the U.S. coal fleet at that time estimated a potential net national CO_2 emission reduction of 40% to 50%. On the economy and domestic jobs front, WRI's CAT™ process can help build a new component within the domestic petrochemical sector that could create long-term career jobs in every state.

The large financial investments made to build the coal power plant fleet in the United States provides an opportunity to leverage the sustainability goal with lower new financial investments and lessens diversion of limited funds away from other state and national needs. WRI's research includes evaluation of biomass blended with coal to aid farm and forestry states with significant amounts of refuse biomass to maximize their clean energy mix and to provide new market opportunities to the farming and forestry industries by leveraging existing coal plant financial assets.

One technology developed with an industry partner to dry and upgrade the energy value of low-rank coals is now being commercialized to enhance the utilization of woody biomass for energy plant feedstock. This WRI coal drying process applied to biomass is called torrification and produces charred wood pieces that possess an equivalent grindability index performance as coal. Grindability is critical if a material is going to be used in the production of energy through gasification. The result is that biomass can be blended with coal and used to leverage existing coal power plant investments.

A yet to be realized environmental benefit lies in the opportunity to leverage coal power plant emission capture systems to capture criteria hazardous air pollutants (HAPs) such as mercury and arsenic that exist within the biomass energy resources. Yes, biomass does possess several criteria pollutants. In addition, as reported by the Partnership for Policy Integrity (PFPI) paper, "Air pollution from biomass energy" updated April 2011, biomass energy plants emit greater amount of certain criteria HAPs than is emitted from coal power plants. PFPI identified, "The HAPs emitted in the greatest quantities by burning biomass include the organic HAPs styrene, acrolein, and formaldehyde, and acid rain gases hydrofluoric acid and hydrochloric acid...Even "clean wood" – that is forestry-derived wood, as opposed to construction and demolition debris – emits these chemicals when burned. Burning clean wood also emits non-negligible amounts of heavy metals." A copy of the paper by the Partnership for Policy Integrity is attached at the end of this written testimony.

On July 12, 2013, the Partnership for Policy Integrity reported on the United State Court of Appeals ruling against the United States Environmental Protection Agency (EPA) that the EPA could no longer allow exempting CO_2 emissions from biomass power plants for purposes of Clean Air Act permitting. The Partnership for Policy Integrity provided expert testimony for the case and reported, "Most new biomass power plants are fueled with wood, and emit 40 – 50% more carbon dioxide than a coal plant, per megawatt-hour electricity generated. The court's decision could affect how states choose to incentivize biomass energy in the future. Massachusetts has already made low-efficiency biomass power plants ineligible for subsidies, based on the large amount of CO_2 they emit."

We see a substantial opportunity via the combined utilization of biomass with coal power plants to lessen human and wildlife health risks by lowering the inventories of HAPs such mercury and arsenic existing in the environment and food-chain. We view this as a very worthy goal given that it is ***the existing quantity of mercury in the ecosystem that has been deemed a human and wildlife health hazard***. We believe this allows policies to explore and implement solutions to reduce the quantity existing in the ecosystem in addition to reducing new emission contributions.

Just as happened with coal, biomass accumulates various elements and compounds. Both produce HAPs during combustion. By working with these processes of nature in which coal and biomass accumulate hazardous substances such as mercury and arsenic and co-feeding this contaminated biomass with coal we can assist in lowering the quantity of mercury and arsenic already existing in the ecosystem and food-chain. This presents an opportunity to integrate biological based environmental remediation for mercury and arsenic via biomass and thereby leverage the investment in multi-HAPs capture control technology installed on coal power plants. The result being an integrated clean energy solution that not only reduces new emissions of mercury and arsenic but perhaps more importantly combines to lessen the existing human and wildlife health risk by cleaning up the unsafe levels already in the ecosystem.

Given that 50% or more of the annual mercury deposition quantity in the U.S. is from foreign sources, we believe that lessening the human health risks will require some means to reduce ecosystem mercury levels in addition to lowering domestic mercury emissions. Integrating the natural process of biomass to uptake contaminants within the ecosystem with existing and coordinated emissions control investments to coal power plants we see an opportunity to achieve lower health risks by lowering the quantity of contaminants within the environment and food-chain. Utilizing the existing coal power fleet provides readily available asset investments to which to retrofit additional emissions control technologies.

WRI recommends that the efficient utilization of energy and financial resources is a key to achieving sustainability goals and energy security. This includes:

1. Coal Upgrading/Drying with added benefits of criteria pollutant removal and lower/elimination of coal fines during rail transport
2. Coal and Coal/Biomass Gasification
3. Coal to Alcohols and Chemicals

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4. Hydrogen and CO_2 Capture/Separation
5. WRITECoal emission management and water utilization for low-rank coals
6. Secondary Biogenic Coalbed Methane
7. Biological CO_2 Capture and BioCrude Oil production
8. Mercury Continuous Emission Monitoring (CEM)

KEY CHALLENGES

- investment uncertainty and risk due to unstable regulations;
- large investment amount required to support pilot-scale and demonstration scale technology de-risking stages of technology advancement;
- new large energy process "game changing" technology takes decades from research conception through pilot, demonstration and commercial scale deployment;
- biomass energy density is significantly low compared to coal such that its applicability for all states as a sustainable energy resources is constrained by the fact that long distance transportation energy consumption beyond 80 to 100 miles can exceed the energy contain within the young biomass; and,
- the segregated nature of the coal and power industry business components results in a lack of integrated strategic planning and implementation from resource extraction, to conversion (i.e., electricity) to power transmission and distribution, and integration of distributed energy resource (DER) utilization technologies, especially intermittent DER technologies.

UTILIZATION OF LOW-RANK COALS

- **Chemoautotrophic (CAT™)** carbon capture bacteria create a biological crude oil that can effectively recycle CO_2 through production of alternative petrochemicals for use in the chemical industry or even as fleet biodiesel fuel. We started our research looking for ways to lower the energy consumption and financial investment resources estimated to be required for conventional underground CCS approaches. Our goals were to provide a lower cost approach that also had geographical flexibility by not being limited to the available geological formations capable of sequestering carbon dioxideation. As WRI advanced this technology we came to understand that it could change the entire perspective about CO_2 being solely a negative planetary and human health hazard and think about CO_2 as a beneficial resource to aid sustainability and energy security national strategic goals. A summary of the WRI's CAT™ process technology is provided in Attachment B.

- **Recycling Energy:** The U.S. Department of Energy (DOE), Energy Information Administration (EIA) and the International Energy Agency (IEA) estimate large growth in world energy consumption through 2035. A key contributor to the growth is the increasing economic expansion in emerging country economies that is moving existing populations from subsistence living conditions to middle class consumerism life styles. This global economic megatrend is a major factor in projections of accelerated consumption of all natural resources on our planet and emissions from extraction and utilization of energy. Attachment C provides a summary of the EIA and IEA projections.

This has motivated WRI to increase our research focus aimed at increasing energy efficiency and devising practical technologies that recycle energy similar to the growth in recycling of paper, plastic, metals, asphalt pavement, etc. Carbon-containing molecules are a key output from both fossil and biomass energy plants that we can work with to invent energy recycle technologies such as our research on WRI's chemoautotrophic process technology described above. By capturing and utilizing CO_2 emissions from large CO_2 emitters such as coal power plants and in turn producing bio-based petrochemical alternative feedstock it is possible to reduce foreign oil imports and their associated emissions. Applied to the current coal power plant capacity within the U.S. a national CO_2 emission reduction of 40% to 50% is estimated. This could achieve a national carbon footprint comparable to natural gas electric power generation plants. An energy systems integration approach creates opportunities to establish a new component within the energy sector that supports jobs nationwide. This provides opportunities to lower the U.S. foreign trade deficit enabled by lower manufacturing costs, retaining domestic cement production, and increasing domestic transportation fuel production.

WRI helped to create a Zero Carbon Data Plant demonstration occurring in Cheyenne, Wyoming. This public-private partnership project, including Microsoft, FuelCell Energy, the City of Cheyenne, the University of Wyoming, Cheyenne Light Fuel and Power, Wyoming Business Council and WRI, leverages a bio-chemical carbon recycle system within nature to achieve a carbon neutral power plant for a Microsoft modular data and computational server. This Zero Carbon Data Plant demonstration facility is designed to use biogas from the Cheyenne Board of Public Utility's Dry Creek Water Reclamation Facility using a molten carbonate fuel cell plant from FuelCell Energy to produce clean power for a Microsoft server module. Future research opportunities include testing and evaluating utilization of CO_2 emitted from the fuel cell and recycling CO_2 through the WRI CAT™ process thereby increasing societal economic sustainability and environmental benefits.

Such opportunities allow us to use innovation to create solutions to pressing issues and needs. As is the essential nature of research we strive to find opportunities where problems are identified. Our thinking therefore must be unconventional so that we may create positive step changes in technological possibilities. By applying unconventional thinking about the problem of CO_2 as an environmental and health hazard to be treated and disposed of as a hazardous substance, we are opening our minds to invent ways to turn CO_2 from an underutilized resource into a key energy portfolio resource to achieve great gains toward sustainable societal goals.

- **WRITECoal™** enhances the value and utilization of low-rank (high water content) coals by extracting the water at power plant input for later use within the plant. This results in lower local water consumption to supply plant makeup water with an estimated 50% to 60% lower water consumption. We think that this is important for water stressed regions of the U.S. The technology was first developed to remove mercury (Hg) prior to feeding coal into the plants thereby simplifying the Hg capture. We project Hg capture of 90% or better depending upon the quantity of Hg locked in the pyrite rock existing within the coal feed. The coal-bound Hg is easily removed whereas the Hg in pyrite is physically locked into the rock material and is not readily liberated for capture. Jigging equipment can be used to remove the pyrite, thereby achieving very high Hg emission capture percentages.

  WRI, also, sees substantial capture of arsenic and selenium and developed multi-pollutant capture technologies to increase the effectiveness of capturing more than just one pollutant. Most capture technologies tend to be highly selective and quickly saturate with one pollutant thereby allowing the other pollutants to flow out the stack with negligible capture percentages. Attachment D provides a summary of WRITECoal™.

  While increasing coal power plant efficiency 3 to 4%, capturing >90% of the mercury and lower CO_2 capture cost, WRI's technology turns the water in PRB coal from a price limiter into a valuable asset. WRI's WRITECoal™ pretreatment utilizes waste heat from coal power plants to evaporate the water which is collected for later use in the plant, thereby delivering usable water with low-rank coals. This is especially important in arid and drought stricken regions of the U.S. where water shortages are increasing.

- **In-Situ Biogenic Coal Extraction** technology developed by WRI entails an advanced system for in-situ enhanced biogenic methane production from coal using naturally occurring microorganisms that normally live in coal. This technology extends the life of current coal bed methane well and pipeline investments, and allows the revitalization of abandoned, played-out wells. Additionally, this technology can produce methane from

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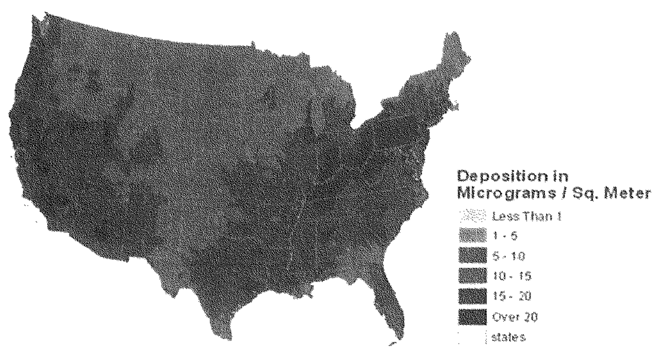
low-rank coal deposits and high-rank "stranded" coal deposits that are currently beyond the reach of financially viable mining technologies. This in-situ biogenic extraction technology, summarized further in Attachment E, is designed to increase domestic methane reserves beyond what is currently estimated by the DOE EIA.

- **Coal Dryer Energy Enhancer** technology increases the energy value of low-rank coals from approximately 8,200 to 11,500 British Thermal Unit/pound (BTU/lb) while also significantly lowering mercury (Hg) content and removing coal fines prior to transport. This is essentially a mine-mouth process that enables removing Hg at the mine site for safe disposal during mine back fill and site restoration to high quality wildlife habitats. A benefit sought by commercial deployment of this technology is to enable a near-zero mercury coal for export that would help lower Hg deposition in the U.S. (mainly western states) from the burning of coal in Asian countries and emissions carried by trade winds to the western U.S.

- Another four projects represent a second integrated program aimed at moving Wyoming up the value chain in energy with technologies to produce liquid fuels, industrial chemicals, and hydrogen while also lowering the cost of CO_2 capture. One of the technologies miniaturizes reactor size through delivering 4 to 5-times better thermal and chemical reaction performance. Another technology substantially improves mercury capture efficiency.

LOWERING MERCURY CONTENT

Understanding Mercury Human and Wildlife Health Risks – As shown in the next figure, high levels of mercury exist in the ecosystem of western states and the Upper Ohio Valley.



Source: US EPA 2005 using Community Multiscale Air Quality model.

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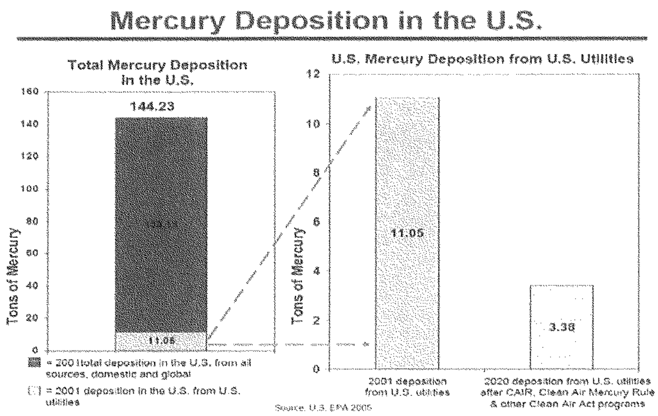
Another key piece of factual data published by the U.S. EPA in 2005 illustrated in the next chart is that of the 144.23 tons of mercury deposited in the U.S. in 2001 only 11.05 tons (7.7%) came from U.S. utilities. Furthermore, mercury emissions for U.S. utilities were projected to decline to 3.38 tons by 2020 as shown in the chart below.



Also, reported by the U.S. EPA is a breakout of domestic mercury emitters illustrated in the next bar chart. U.S. Utility Coal Boilers represented about one-fourth the total domestic mercury emissions prior to 1999. A key policy question worthy of consideration is, "What is the cumulative contribution by various sources to the mercury existing in the U.S. ecosystem?" Based upon the three EPA data charts regarding mercury, it seems apparent that the majority of mercury existing within the ecosystem and deemed a human and wildlife health hazard are primarily attributable to sources other than the U.S. Utility Coal Boilers. This begs the next questions, "Could combined policy that includes removal of mercury from the ecosystem and reducing new emissions best achieve lowering of the human and wildlife health hazard?"

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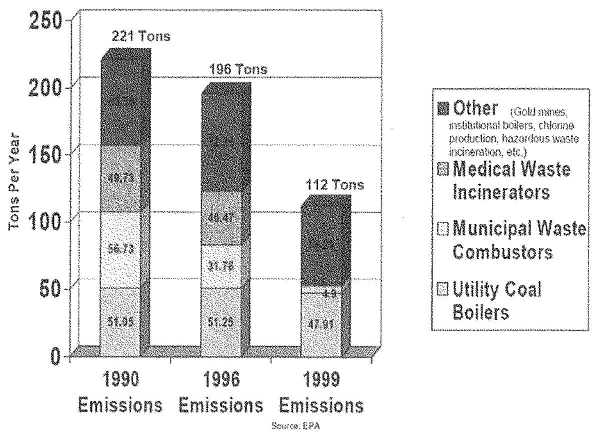
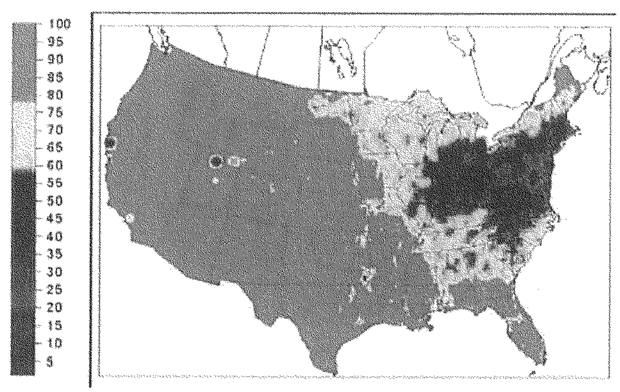
Mercury Emissions Have Dropped 45% Since 1990



Presently, a large percentage of new mercury depositing in the western states is attributable to coal burning power plants and cement production in Asia. The figure below from the Electric Power Research Institute (EPRI) illustrates the percentage of mercury from foreign sources depositing in the U.S. The amount of mercury depositing in these states is expected to increase over the next few decades due in large part to predicted economic growth in Asia. The WRI Coal Drying Energy Enhancer technology described above provides a means to remove nearly all mercury from low-rank coals prior to export to Asian markets. This provides an U.S. developed technological solution to protect western states from growth in future mercury deposits while dealing with the practical reality of environmental and economic policies in other countries.



Percent of mercury deposition originating outside the United States {Source: EPRI}

Continuous Emission Monitoring for Mercury we worked with the Electric Power Research Institute (EPRI) and the National Institute for Standards and Technology (NIST) with funding support from the U.S. DOE and the Environmental Protection Agency (EPA) to advance Continuous Emission Monitoring (CEM) protocols and evaluate/improve the CEM equipment.

CARBON CAPTURE AND SEQUESTRATION (CCS) TECHNOLOGIES

Our thinking has evolved to consider CO_2 as an economically productive and valuable resource that facilitates national security and competitiveness in the global economy. We are focusing our ingenuity to maximize "Sustainability for Living in a Carbon-Rich World." In addition, to using biotechnology to convert CO_2 into a chemical feedstock for U.S. manufacturers to produce higher value products, there is significant economic potential to utilize the domestic supply of CO_2 to increase domestic oil production using CO_2 enhanced oil recovery techniques. Creating the infrastructure and connecting the various business opportunities could enable energy intensive industries, such as manufacturing and data centers, by providing an income stream from sale of their CO_2 emissions to other industries that can recycle/reuse the CO_2. Our view is that creating the market demand for CO_2 will be far more effective and beneficial for the overall U.S. economy than solely implementing a CO_2 emission reduction policy approaches.

Our colleagues within the University of Wyoming, Wyoming Geological Survey, Wyoming Pipeline Authority and Governor Matt Mead's office are implementing long-term strategies to manage carbon dioxide. For example, the state of Wyoming has developed a strategy to expand the CO_2 pipeline network throughout the state to maximize enhanced oil recovery over the next couple of decades while preparing the infrastructure for delivering CO_2 to underground sequestration facilities. Full implementation of this strategy will form a long-term public-private partnership to address the concerns for CO_2 emissions while providing economic wealth creating business and job opportunities for the oil sector. In addition, the state of Wyoming has provided approximately $70,000,000 for clean energy research and development to advance environmentally safe coal utilization, oil, natural gas, wind, nuclear, solar, geothermal and hydropower technologies. The state is pursuing an "All-of-the-Above" energy research and technology development portfolio strategy that includes integration across traditionally segregated energy sectors and within sectors, such as coal. Coal is perhaps one of the most segregated vertical subsectors with the energy sector. This has essentially blocked strategic investment in research across the subsector due to lack of a single entity positioned to coordinate long-term strategic planning and investments to resolve environmental concerns.

The WRI chemoautotrophic (CAT™) CO_2 utilization technology mentioned earlier is a biotechnology invention that creates economically beneficial uses for CO_2. WRI is bringing forth a technology that allows thinking about CO_2 as a long-term beneficial resource that can facilitate achieving economic sustainability and energy security while increasing wealth creation to bolster economic prosperity in all states.

RECOMMENDATIONS

Based on WRI's experiences and expertise, I recommend that Congress take the following actions:

- Formulate a flexible integrated clean energy technology research investment portfolio and priorities to achieve best performance within local and regional constraints.
- To affect a Best-Portfolio National Approach, a national strategy for "All-of-the-Above" energy resources and utilization technologies needs to accommodate:
  - the real-world substantial differences in local energy resources,
  - weather, altitude, water availability, wildlife and infrastructure assets,
  - differences in local energy consumption and the purpose of that consumption,
  - consumption of energy locally and the associated emission footprint to supply end-use energy for consumption by other states necessitates that Federal mandates for states should provide goals to energy producing states that differ from energy consuming states,
- Consider policies that allow exploring solutions for Living in a Carbon-Rich World in addition to Living in a Carbon-Constrained World,
- Consider allocating increased funding to support the utilization of carbon dioxide to stimulate the transformation of this abundant compound from something to be avoided to something which can be used to increase chemical feedstocks, biofuels and support national energy self-sufficiency,
- Allocated resources for research to support the sustainable and environmentally safe use of fossil fuels, especially energy efficiency advancements.
- Federal government take the leadership role of strategically planning and advancing energy efficiency improvements and environmental impact reductions across the entire coal sector.

CLOSING REMARKS

WRI has taken an integrated approach to provide sustainable solutions that bring down the costs of energy production and utilization of coal and other traditional resources by combining our knowledge base with emerging technologies. The many boom and bust cycles that we have experienced in the energy sector are a function of the marketplace. The way in which we can minimize the downside of this fact of life is through an aggressively innovative partnership between industry, research entities and the federal and state governments. This will ensure that our energy technology portfolio will deliver benefits to the U.S. consumer and protect the environment.

I would note , for example, that the state of Wyoming is investing in and implementing a long-term strategic plan to maximize the entire energy portfolio within Wyoming while positioning infrastructure to address CO_2 long-term storage. This is precisely the kind of activity the federal government should encourage. Making the best use of limited financial investment resources in addition to efficient utilization of energy resources is a key to achieving national sustainability goals and energy security.

In closing, a strong commitment to this kind of portfolio approach that avoids a one size fits all solution, will facilitate innovation and sustainable economic growth. Continued Federal funding of scientific research and technology development is essential to enable maximizing energy efficiency and productivity of our country in the most environmentally and economically sustainable ways.

Again, thank you for the opportunity to appear before you. I would be pleased to answer any questions the Subcommittee may have.

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ATTACHMENT A

OVERVIEW OF WESTERN RESEARCH INSTITUTE

Located in Laramie, WY, Western Research Institute (WRI) is a team of 83 scientists, engineers, technicians and management professionals working on both scientific research and applied RD&D to bring forth scientific knowledge, solutions and technologies in the fields of energy, environmental remediation and emission control, and longer lasting highway materials.

WRI's historical beginnings in Wyoming start in 1924 supporting high sulfur oil processing in Wyoming. WRI was established in 1983 when the U.S. Department of Energy (DOE) de-federalized the Laramie Energy Technology Center. The state of Wyoming via the University of Wyoming (UW) created and implemented a plan that retained the laboratory assets and jobs in Laramie by establishing the University of Wyoming Research Corporation d/b/a Western Research Institute as an independent nonprofit 501(c)3 cooperating entity with UW, though not UW or state employees. The resources saved by the state include a 22-acre research park in Albany County located just north of Laramie and the former DOE Laramie Energy Technology Center (LETC) building on the northwest corner of the UW campus. WRI retained ownership of the 22-acre park environmental issues and ownership of LETC building was transferred to UW. Presently, WRI leases space from UW its laboratories and office spaces within this building.

WRI's Mission Statement reflects the broad scope of topics, national and global based market sectors and beneficial contributions pursued.

WRI Mission Statement

- Western Research Institute provides sustainable societal benefits by solving complex science and technology problems.
- We collaborate with partners to define the challenges, extend the body of knowledge and deliver innovative solutions in energy, environment and transportation technologies.

Given the lengthy one to two decade timeframe to invent "Game-Changing" energy process plant technologies that achieve societal goals and then scale up that invention into commercial viable plants, it is vital to monitor megatrends in addition to the identified current day issues and needs. As researchers and technology developers within the energy sector it is vital that we target our early stage research problem and opportunity statements on the future challenges and opportunities requiring solutions 10 to 20 years from today. This strategy provides a research and technology pipeline with technologies nearing and ready for commercial deployment while preparing scientific knowledge and new inventions to address the problems and megatrend opportunities a few decades into the future.

Key highlights of WRI illustrated the agility and adaptability to adjust to changes in industry technology solution needs and regulations include the following:

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1. WRI is a multifaceted organization with a highly diverse suite of expertise, staff experience, intellectual property and research and technology development equipment and facilities.
2. WRI's clients, research partners and stakeholders are very diverse with both local, national and international market interests and business operations.
3. WRI consists of three Business Units: *Energy Production and Generation* (EP&G), *Waste and Environmental Management* (WEM), and *Transportation Technologies* (TT).
4. WRI's business portfolio has evolved to follow the needs of the various market sectors served by WRI and consists of a majority of applied Research, Development and Demonstration (RD&D) with a strong basic scientific research component with TT and as needed scientific research within EP&G and WEM.
5. Strong collaborative with universities such as the University of Wyoming and junior colleges to assist in educating and developing the skilled workforce talent people to support quicken commercial deployment of successful research and technology developments.
6. Over the past three years, WRI has substantially diversified its client base to foster an increase in commercialization of our research and technologies. This diversification shift to commercial industry partner applied research achieved a 47% increase in FY2013 over FY2011. A further growth of approximately 50% in commercial business for FY2013 versus FY2012 has been continued this focus on industry commercial viable research and technologies.

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ATTACHMENT B

CAT™ Process: A CO_2 Capture and Re-Use Technology for Fossil Fuel Plant Emissions

Coal utilization will continue to be a key factor in meeting the energy demand both domestically and internationally in the near future (Bauer, 2009). As shown in Table B-1, coal use and CO_2 emissions in the U.S. are expected to increase in the next few decades from 23 to 26 quadrillion Btu per year and 2.1 to 2.5 billion metric tons/yr, respectively. Additionally, CO_2 emissions from the transportation sector are predicted to be equal to that of emissions from coal by 2030. If emissions from one of these CO_2 sources could be reduced, then up to a 40% reduction in emitted CO_2 could occur. Without accelerated technology development to address CO_2 reduction, along with options for efficient and greener forms of energy supply from coal-based technologies, coal use and indirectly the economic progress of the country will be severely impacted. WRI's patent-pending CAT™ process could be used to capture, for example, coal-fired CO_2 emissions and produce biodiesel that replaces petroleum diesel, thus lowering the rate of CO_2 emission into the atmosphere.

Table B-1. Dominance of Coal in Energy Supply and CO_2 Emissions

Energy Source	Unit	Energy Use		Unit	CO_2 Emission	
		2006	2030		2006	2030
Coal	QBtu/yr	23	26	bmt/yr	2.1	2.5
Gas	QBtu/yr	22	24	bmt/yr	1.2	1.3
Nuclear	QBtu/yr	8	9			
Oil	QBtu/yr	41	38	bmt/yr	2.6	2.6
Renewables	QBtu/yr	6	14			
Total	QBtu/yr	100	111	bmt/yr	5.9	6.4
Change (Total)	%		11	%		8.0

Table from EIA, 2009.

The CAT™ Process. WRI's patent-pending CAT™ process is a novel biological carbon capture and re-use technology that can be added to stationary carbon dioxide emitters. This technology is not dependent on light, which affords it a number of advantages over current algal technologies. Current research and development efforts are concentrating on use of the CAT™ process for biodiesel production, but this process could be used for generation of other fuels and chemicals. Our models predict that biodiesel can be produced for approximately \$3 to \$5/gallon using the CAT™ process. This promising technology is currently at the research and development stage and is in need of funding opportunities to bridge the "valley of death" in the funding landscape, which correlates to the technology development phase between early research and development and pilot scale technologies.

The CAT™ carbon capture and re-use process offers a safe and reliable alternative to geological storage, in addition to providing a low cost carbon capture technology to the emitter. WRI's CAT™ process competes with other cutting edge biological CO_2 capture technologies in terms of net efficiency, capital costs and plant availability. Deployment of the CAT™ technology would enhance the economic and energy security of the U.S. through the development of a technology that will (1) effectively capture CO_2 from stationary sources, (2) produce energy-dense, infrastructure compatible liquid fuels/bioproducts from CO_2, thereby reducing petroleum imports and CO_2 emissions (Figure B-1); and (3) minimize the efficiency reduction and financial expense of GHG emissions controlled facilities, such as industrial and manufacturing facilities and utilities.

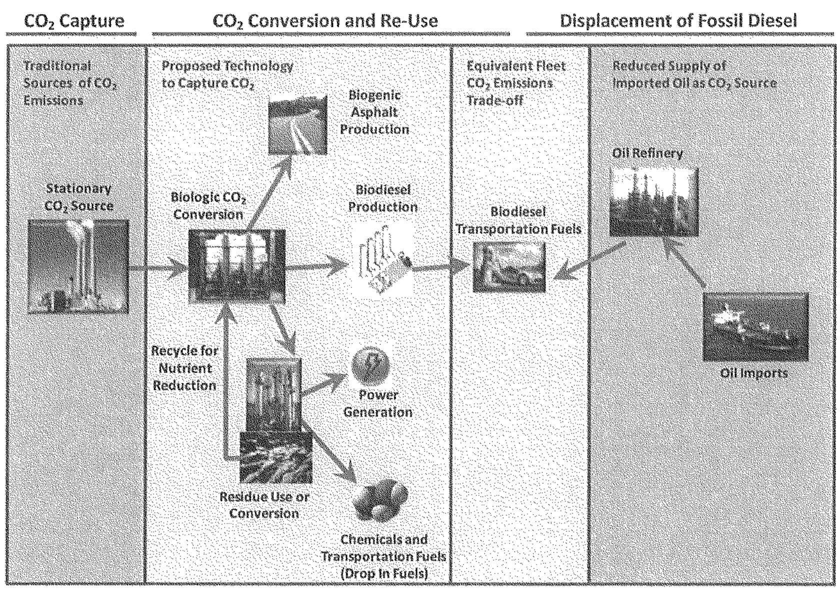

Figure B-1. CAT™ process schematic showing "Big Picture" global CO_2 reduction pathways.

The integrated societal energy system CO_2 reduction results when the synthetic diesel is used to displace conventional diesel consumption – achieving a second use of the carbon within coal prior to the eventual CO_2 emission from vehicle exhaust pipes. While the transportation sector CO_2 emissions are not directly reduced, the fact that the CAT biodiesel fuel prevented power plant CO_2 emission from entering the atmosphere we achieve an integrated societal system reduction in CO_2. A descriptive formula comparison of Today (without CAT) and a Future (with CAT) illustrates the how an integrated societal energy system achieves lower net CO_2 emissions:

Today's Total CO_2 (without CAT) = Power Sector CO_2 + Transportation Sector CO_2 + Other CO_2 Emitters

Future Total CO_2 (with CAT) = Power Sector CO_2 lowered by 80% to 90% + Transportation Sector CO_2 + Other CO_2 Emitters

The CAT™ process uses chemoautotrophic bacteria (CAT bacteria) to capture and re-use carbon dioxide from flue gas, so these bacteria effectively recycle carbon that is likely from a fossil source for biodiesel production. To consume carbon dioxide from flue gas, the CAT bacteria get energy by oxidizing a reduced inorganic material. A synthetic symbiosis is then established to recycle the produced oxidized inorganic material, and this is accomplished by the use of reducing bacteria (RB). The RB consumes organic material while reducing the oxidized inorganic material. The organic material is derived from waste products from both the CAT™ process and other processes. A third type of bacteria is used to convert those waste products into organic material suitable for use by the RB (Figure B-2). RB and CAT bacteria will be harvested and further processed for biodiesel production.

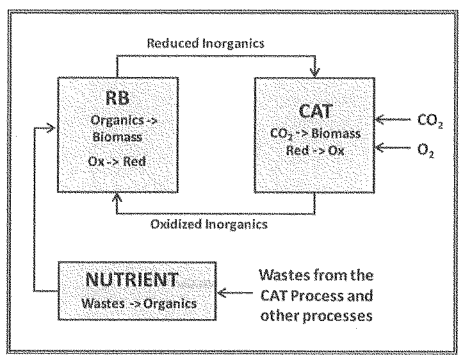

Figure B-2: Schematic of the CAT™ process.

Potential Applications. WRI has modeled the CAT™ process as an add-on to several existing technologies. The CAT™ process can be used to recycle CO_2 in various fuel emissions, such as those from coal, natural gas and biomass. This process is not limited to use with utilities but is applicable for a wide range of industrial CO_2 sources, such as cement and lime production, refineries, and others that use a fuel to produce heat and/or steam. Modeling results have shown the CAT™ process to produce approximately 53 gallons of biodiesel/ton of CO_2 captured. If the CAT™ process is used to capture carbon from a 100,000 ton of carbon dioxide per year emitter, we estimate that 5,329,930 gallons of biodiesel can be produced each year.

The CAT™ process can also be an economic driver for advanced coal-to-liquid technologies, such as gasification Fischer-Tropsch. Only 37% of the carbon entering the Fischer-Tropsch technology is converted to the liquid product, while 63% of that carbon is emitted as CO_2. If the CAT™ process is used to capture 75% of those carbon emissions for conversion to biodiesel, an additional 40% or more of the synthetic diesel could be produced. This completely changes the economics of the Fischer-Tropsch process to a more financially attractive investment.

Western Research Institute is investigating a wide range of applications for the CAT™ process in coal-based systems as well as non-coal applications.

Economics. Economic analysis performed at WRI was performed with an assumed biodiesel price of \$3/gallon. Preliminary assessments of costs and revenue of a CAT™ process facility that captures 90,000 tons of carbon dioxide per year are listed in Table B-2. The calculated costs and revenues do not include potential income earned by selling carbon credits.

Table B-2. Predicted economics of the CAT™ process when deployed at a 100,000 ton of carbon dioxide per year emitter.

	Cost
Capital	\$40.85M
Operation and Management	\$7.6M/year
Revenue	\$24.35M/year

Benefits. The CAT™ process has significant advantages over carbon capture and re-use technologies that rely on light, including many algal technologies. Table B-3 below summarizes these advantages. The independence from light of the CAT™ technology allows bacteria to be grown in deep, cylindrical reactors that can be partially buried. These reactors require significantly less capital than custom photobioreactors used by algae. In addition, the CAT™ technology uses 95-97% less land than open ponds of algae to produce the same amount of biodiesel. Since the reactors are in a closed system, unlike open ponds of algae, evaporative water losses are not an issue, which makes this technology more attractive in regions with limited water. We believe that these advantages would make this system an attractive carbon capture and re-use technology for existing stationary carbon dioxide emitters, especially power utilities and cement plants. Introduction of this biodiesel into the market would displace some of the petroleum diesel used, which in turn would slow the rate of carbon dioxide release into the atmosphere in an integrated national accounting approach.

Table B-3: Summary of benefits of the CAT™ process compared to algal technologies, particularly open ponds of algae.

	CAT™ Process	Algae
Productivities	On par with algae	On par with CAT
Reactor Type	Closed reactors, commercially available	Open raceway ponds, high surface area photobioreactors
Climatic Requirements	No particular requirements. Reactors may be insulated or buried to maintain temperature	Reduced performance in climatic extremes or locations with reduced sunlight. Reactors may require heating
Land Requirements	Relatively small footprint due to deep cylindrical reactors. A 95-98% reduction is estimated for larger CO_2 sources.	Large foot print, productivity maximized when reactors are no greater than 10-15 cm deep
Water Use	No evaporative losses	High evaporative losses

Next Steps. The CAT™ process is in the early research and development phase and has entered into the "valley of death" of the funding landscape. This technology is not brand new and thus is not eligible for many federal grants. However, since the technology is not yet at a pilot scale, industry is not as likely to be willing to invest in this stage of technology. While the Department of Energy ARPA-E program can provide funding opportunities for research and development activities through scale-up, these opportunities appear to only be available to technologies that were funded by ARPA-E at an early stage and focused on photobioconversion technologies. A funding mechanism for technologies, such as the CAT™ process, that are in this "valley of death" would accelerate the movement of promising technologies to the market.

References.

Bauer, C. *Energy Production and CO_2 Emissions: Protecting our Air Quality*. in *Air Quality VII, International Conference*. 2009. Arlington, VA.

EIA. 2009; Available from: www.eia.gov.

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ATTACHMENT C

Megatrend and Overarching Market and Economic Considerations

The following Megatrend, Market and Economic Conditions are used to focus WRI research on the challenges and opportunities.

Global economy will grow lead by emerging country economies and economic trading zones. It is reasonable to expect the economy in the Organisation for Economic Co-operation and Development (OECD) countries to experience modest real growth over the next three decades, including riding well through recessionary down periods. Energy consumption is often used as a measure of economic activity. The chart from the U.S. Department of Energy, Energy Information Administration (EIA) 2013 Energy Outlook Quick Look report shown in Figure C-1 illustrates the sharp decline in U.S. energy consumption associated with the economic decline following the 2008 Financial Crisis and the resulting Great Recession. The low gradual energy growth through 2040 reflects energy efficiency gains and relatively low U.S. growth forecast for the EIA Reference Case. The forecast is flat to negative for low economic condition scenarios.

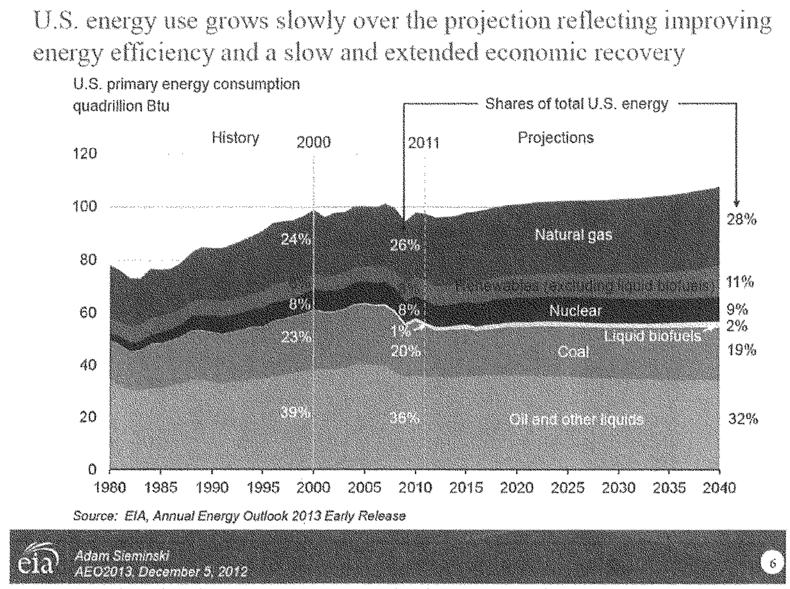

Figure C-1. U.S. DOE Energy 2013 Outlook Quick Look Energy Consumption

Figure C-2 from the U.S. EIA and Figures C-3 and C-4 from the International Energy Agency (IEA) forecasts greater energy consumption increases for emerging economies compared to the OECD countries.

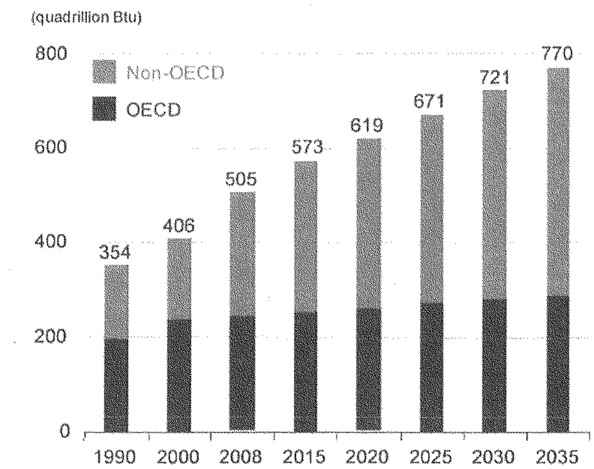

Figure C-2. U.S. DOE EIA World Energy Consumption Forecast

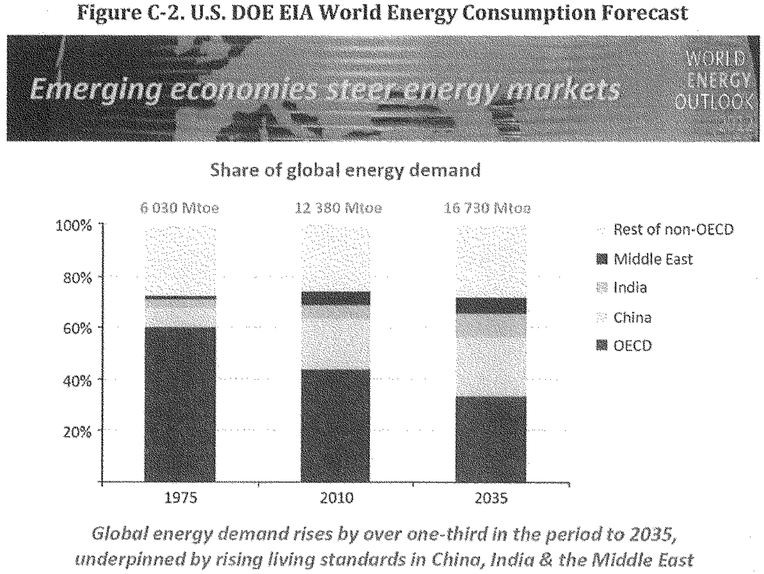

Figure C-3. International Energy Agency Global Energy Consumption Forecast

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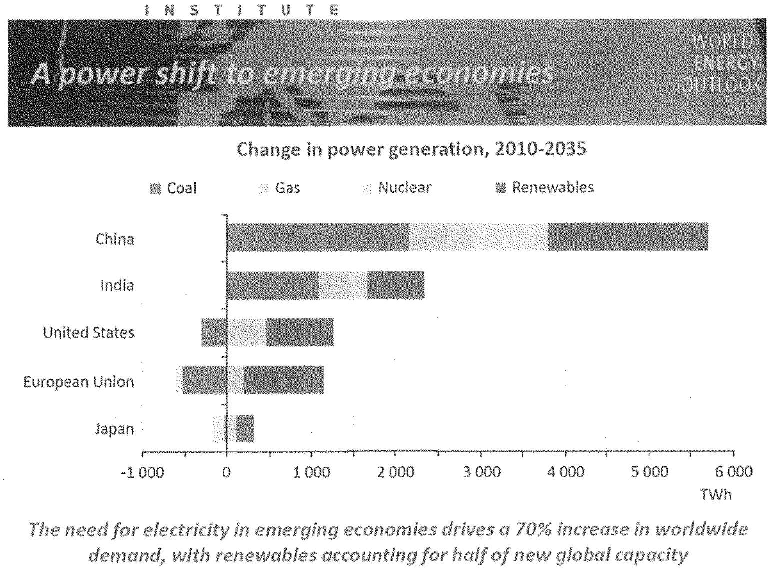
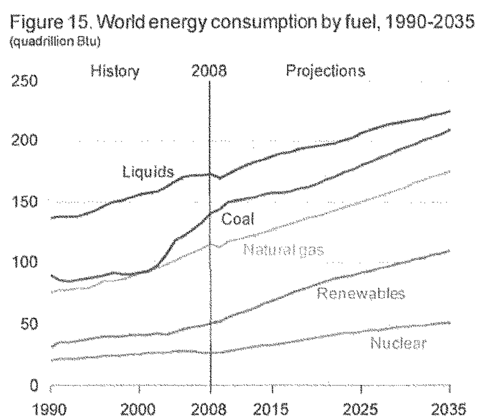


Figure C-4. International Energy Agency Global Electricity Generation Forecast

The U.S. DOE EIA global energy consumption forecast by various energy types illustrated in Figure C-5 highlights the megatrend demand for liquid energy fuels. This projection provides a clear picture and motivation to focus on recycle energy resource through multiple uses of carbon containing molecules in both fossil and biomass energy natural resources.



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ATTACHMENT D

WRITECoal™ Technology – An advanced Coal-based Technology to Enhance Coal Quality, Reduce Air and Water Emissions, Increase Plant Efficiency and Reduce Cost of Electricity

Western Research Institute (WRI) with the support of the U.S. Department of Energy, National Energy Technology Laboratory (USDOE, NETL), the states of Wyoming and the North Dakota and a wide range of utilities and industry organizations[2] have been developing a novel patented and patent-pending coal treatment/upgrading and multi-pollutant emissions control technology that increases efficiency and reduces the cost of electricity (COE) for both the existing fleet of coal-fired electricity generation units (EGUs) and new coal-fired EGUs, such as Integrated Gasification Combined Cycle (IGCC) and supercritical air-fired and oxy-fired plants.

The integration of the WRITECoal™ technology into an existing nominal 600MWe subcritical low-rank coal-fired power plant or new construction plant results several benefits. A previously untapped benefit is the ability to utilize the water delivered with low-rank coals to lower power plant consumption water from community water supplies. For example, subbituminous coal may supply 720 gallons of water per 1,000 tons of coal. This amounts to approximately 300,000,000 gallons for water in Wyoming coal production that has been untapped each year.

- Recovery of the water in low-rank (high water) coals evolved from the WRITECoal™ process for use at the power plant, requiring particulate removal only[3] - an untapped water-rich resource,
- The use of plant waste heat for drying increases energy efficiency,
- Increased plant power offsets parasitic power (important with future retrofit for carbon capture options),
- Reduction of emissions, such as mercury, NOx, SO_2, and CO_2 emissions on lbs/MWh basis, as well as on a percentage removal basis,
- Elimination of the need for a combustion or partial oxidation facility at an offsite or minemouth and associated cleanup of process streams, both gas and water,
- Elimination of the spontaneous combustion or dust/fines issues associated with transporting and storing thermodynamically unstable partially dried fuel, and
- Purchase coal from a variety of producers, not from a limited number of suppliers of a low-moisture, low-mercury processed coal at a higher price.

The following provides several examples of the retrofit integration of the WRITECoal™ process with subcritical air-fired and oxy-fired plants. In addition, the performance of integrating the WRITECoal™ process into a gasification/IGCC plant application is presented. There are other coal-fired applications, such as supercritical oxy-fired EGUs and new gasification Fischer Tropsch coal to liquids plants that are applicable, but not presented herein.

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[2] Includes State of Wyoming, State of North Dakota, North Dakota Industrial Commission/Lignite Research Council, Electric Power Research Institute, Basin Electric Power Cooperative, Detroit Edison, Montana-Dakota Utilities, Alliant Energy, Southern Company and SaskPower.

[3] Since the water recovered is free of regulated trace metals and organics and with conventional suspended solids removal, it can be used in the plant without further treatment.

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WRITECoal™ Process and Performance

The WRITECoal™ process is a patented and patent-pending two-step thermal coal upgrading and multi-pollutant emissions control methodology. In the first step, raw coal is heated to a temperature not exceeding 300 °F wherein the free water and most of the more tightly bound water is evaporated and removed. No evolution of mercury and other volatile metals (e.g., arsenic and selenium) occurs in this step allowing for water recovery without treatment for metal species removal. In the next step, the completely dried coal is heated to a temperature of 500-600 °F, wherein mercury in coal is volatilized and removed by an inert sweep gas. High temperature (500-600 ºF) sorbents, capable of capturing volatile metals, such as mercury and arsenic, have been developed to avoid the thermal energy efficiency loss resulting from cooling the sweep gas to 275 °F to enable conventional activated carbon sorbents to effectively capture the volatile metals. A relatively small sweep gas stream compared to plant exhaust stack gas flow is enabled by the WRITECoal™ process. This smaller volume of sweep gas creates higher volatile metals concentration that allows the sorbents to perform more efficiently compared to post-combustion emission capture in the large more dilute plant exhaust stack gas stream.

Coal Upgrading. For subbituminous coals, such as from the Powder River Basin (PRB), the WRITECoal™ process produces a coal that is low in moisture (<1.0%), low-sulfur (<0.6%), high heating value (11,000-11,500 Btu/lb), low in mercury and other volatile trace metals, such as arsenic and selenium (e.g., <0.03 ppmd mercury) and maintains a high volatile matter content and a high O_2 content compared to bituminous coal – important in integration of the process with oxy-combustion and gasification/IGCC systems.

Emission Reduction. When coupled with native capture with the fly ash and an oxidizer additive, the WRITECoal™ integrated retrofit process is estimated to achieve 87-92% mercury removal without the need for large volume post-combustion activated carbon injection (ACI)-based Hg control; and with pre-combustion physical separation technologies, such as air jig, mercury removal efficiency to consistently exceed 91%.

In addition, the WRITECoal™ product reduces NOx emissions by a dramatic 13% to 40% reduction in the flue gas. The impact of NOx emissions reduction on integration of the WRITECoal™ technology is significant from both a regulatory compliance and NOx credit perspective.

Table D-1. Characteristics of Typical Raw and WRITECoal™ Treated Low-Rank Coal.

Parameter	Wyoming PRB Coal		ND Lignite	
Proximate Analysis (wt%, as received)	Raw	WRITECoal™ Product	Raw	WRITECoal™ Product
Total Moisture	28.4	<1.0	36.55	<1.0
Ash	4.82	6.14	6.62	10.20
Volatile Matter	32.64	43.93	31.26	43.20
Fixed Carbon	34.14	48.93	25.57	45.60
Higher Heating Value (Btu/lb)	8,716	11,188	6,864	10,877
Mercury (ppmd)	0.126	0.025	0.184	0.083
Arsenic (ppmd)	4.2	1.4	10.4	6.5

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Water Recovery. Another important benefit of the WRITECoal process is that it is possible to recover the water associated with the coal, typically 28-30% for PRB coals and 38-40+% for lignites found in states such a North Dakota and Texas. As mentioned the two-step WRITECoal™ process first removes water without volatile metals and other organic species, while the second step releases and captures the volatile metals from a relative low volume, dry sweep gas. The recovered water is clean with only suspended solids requiring filtration before being used within the plant. The water can supply the 50% to 60% of the boiler feed water makeup, or a portion of scrubber water or even a small fraction of the cooling water makeup water, thereby using less local water supply.

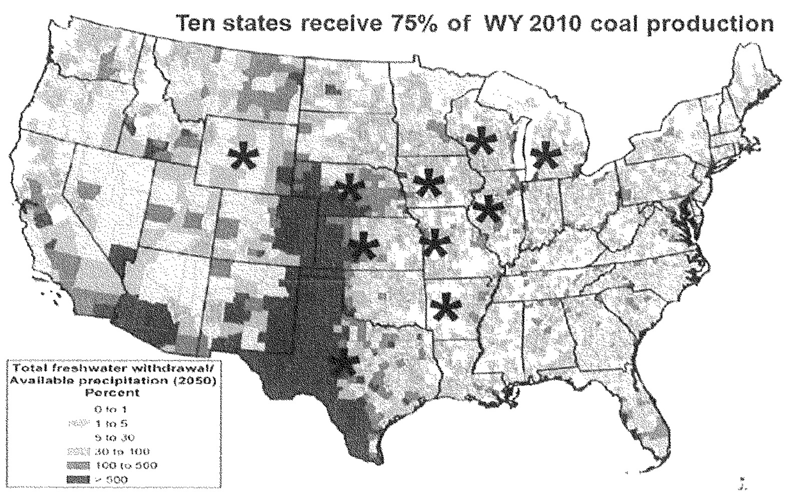


Figure D-1. National Resources Defense Council Map of US Showing the Areas of Drought Distress with Major Markets for PRB Coal Overlaid

Retrofitting Subcritical PC Coal Fleet with WRITECoal™ Technology

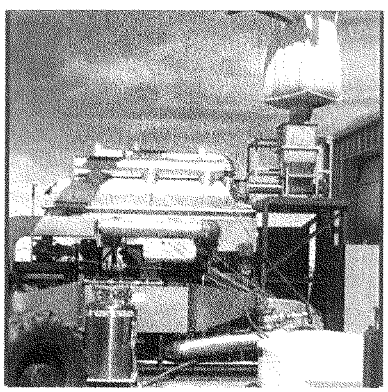
Retrofit Existing Fleet without Carbon Capture.

Efficiency. ASPEN Plus® modeling of the integrated WRITECoal™ retrofit based on a base case of 577MWe (net) PRB coal-fired plant and a 570MWe (net) lignite-fired plant with and without the WRITECoal™ process resulted in increased power output due to efficiency gains and the capacity to increase coal-firing. For example, it is possible to generate 34MWe (5.9%) of additional power by increasing coal feed by 4.4% for the PRB coal-fired plant and 30MWe (5.2%) additional power for a lignite plant with only a 2.2% increase in coal firing. The results showed a 3.4 to 3.6% increase in boiler efficiency gain up to 88.4% for the lignite and PRB cases with WRITECoal™ integration, translating to a 0.5 to 1.0 percentage increase in net plant efficiency. For example, a 1% increase in absolute net plant efficiency fleet-wide in coal-fired plants would result in about 60 million tons/year reduction in CO_2 emissions in the U.S.

Economics. Economic analysis (Jan 2009$) indicate that the Present Worth Revenue Requirements (PWRR) advantage for a WRITECoal™ retrofitted lignite plant was 26.3% and 11.7% compared with the same plant with activated carbon injection (ACI) and TOXECON, respectively for the lignite case and 8.2% for the PRB case compared to ACI deployed plant. The capital cost for a new subcritical 600MWe ND lignite-fired plant and PRB coal-fired plants without CO_2 capture and storage is estimated at $3,040/kWe and $2,870/kWe respectively. WRITECoal™ process total installed capital costs for the lignite-fired and PRB coal-fired subcritical plant translates into a cost of electricity (COE) advantage of 1.1 cents/kWh for the WRITECoal™ process compared to a new sub-critical lignite coal-fired plant COE of 6.7 cents/kWh.

Retrofit to Carbon Capture.

A second retrofit option is the conversion of an existing coal plant into an oxy-combustion plant with carbon capture. The conversion of the existing fleet to carbon capture results in a large increase in auxiliary power (parasitic) power and increases the cost of electricity by up to 80% with some carbon capture technologies. This results in a de-rating of the existing plant due to the fact that the plant does not have the capacity to simply increase coal throughput. As a result only options are to (1) take a major de-rating of the existing plant, (2) purchase power from a carbon capture plant to offset the parasitic power, or (3) install additional facilities like natural gas combined cycle plant to offset the parasitic power. Pilot-scale testing at 1 MWth-scale, modeling studies and costs and LCOE of an oxy-fired subcritical plant was conducted. Figure D-2 shows the mobile 1-2 MWth WRITECoal™ pilot plant integrated with a 1 MWth oxy-combustion pilot plant at Southern Research Institute.



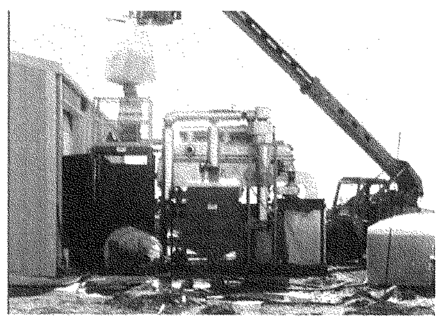


Figure D-2. Mobile WRITECoal™ 1-2 MW_{th}-scale pilot plant at WRI that can be integrated into pilot combustion system

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Efficiency and Levelized Cost of Electricity (LCOE). Efficiency modeling and LCOE of such as oxy-combustion retrofit are shown in Table D-3 and indicate that the purchasing of power does not increase efficiency and increases the COE from 6.8 cents/kWh for the raw coal case. However, the installation of high-efficiency Natural Gas Combined Cycle (NGCC) to cover the parasitic power associated with carbon capture increase efficiency by 4.85% and reduces the LCOE to 5.8cents/kWh from the base of 6.8 cents/kWh. This is a major increase in efficiency and more importantly a major reduction in the cost of electricity when deploying carbon capture to the existing fleet of coal-fired subcritical plants.

The 5.8 cents/kWh for the WRITECoal oxy-combustion with high-efficiency NGCC has equivalent LCOE of a new subcritical plant without carbon capture.

Table D-3. Summary of the Efficiency and Costs for Retrofit of Existing Subcritical Coal-fired Unit to Oxy-combustion with Carbon Capture.

	PRB Oxy-Fired with CO_2 Capture Retrofit		
Costs Jan. 2012 $	**Case 1 Base Raw**	**Case 3 W-Coal w/ Purchase Power**	**Case 4 W-Coal w/ NGCC**
Performance			
CO_2 Capture, %	90	90*	83*
Gross Power-Coal, MWe	590.0	590.0	641.5
Gross Power-NG, MWe		191.2	149.3
Net Power, MWe	401.0	401.0	592.0
Efficiency Gains over Base %	0.0	0.0	4.85
Costs			
TCR (1), 1000$** **$/kW	1,110 2,800	1,110 2,800	1,420 2,400
Fixed O&M, 1000$	24.80	24.80	32.20
Var. O&M, 1000$(4)	69.70	125.30	86.53
Total O&M, 1000$	94.50	150.10	118.80
PWRR, 1000$	1,870	2,560	2,360
LCOE, cents/kWh	**6.8**	**9.3**	**5.8**

*Assumes purchased power is from 90% CO_2 capture EGU.

WRITECoal™ Gasification/IGCC Technology New Plant Application

WRITECoal™ Gasification /IGCC. The WRITECoal™ process can also provide the industry with an economical method of environmental compliance for new plants such as IGCC using low-rank lignite and subbituminous coals, termed WRI's "**WRITECoal™ Gasification/IGCC**" technology. This patent-pending integrated technology not only improves gasifier efficiency, but also features CO_2 recycle to generate additional CO feed to the water-gas-shift reactor thereby producing additional H_2 for power generation and/or chemical production.

The WRITECoal™ gasification/IGCC technology is based on three advantages/benefits of the integrated system; (1) the reduction of moisture (to near zero percentage by weight) in the WRITECoal™ product to the gasifier results in lower gasifier size (capital costs); (2) control of the oxidation of carbon to CO results in enhanced volume of hydrogen in syngas to the gas turbines, allowing reduced fuel feed for the same gas/steam turbine output; and (3) the WRITECoal™ process uses as much waste heat as possible and maximizes gas turbine power. The net result of these three features is a reduction in gasifier capital from a reduction in size and parasitic load from the Air Separation Unit (ASU) and increased power output from the integrated system per unit of coal feed.

The WRITECoal™ integrated gasification/IGCC generates a higher CO+H_2 syngas of >82% and a lower CO_2 content (~5.1%) especially advantageous for chemical production, such as H_2 production. Cold gas efficiency, a measure of the efficiency of the gasifier, is increased by 5% with the addition of WRITECoal™. The high CO and low CO_2 reflect the higher efficiency of gasification with the treated coal and the lower consumption of oxygen (Bland et al., 2012). The WRITECoal™ gasification/IGCC process can be deployed with nearly all of the commercially available gasification systems and positively impact the efficiency and ultimately the COE which varies with gasifier and IGCC subsystem selection.

Efficiency and LCOE. A summary of the performance and Levelized Cost of Electricity (LCOE) of WRITECoal™/IGCC for power production using three different gasifiers is presented in Table D-4. The data establishes that 3.28 to 4.81% efficiency increases with the three gasifiers as a result of the integration of the WRITECoal™ gasification, including moisture removal/coal upgrading and the recycle of CO_2 to the gasifier compared to the raw coal case without CO_2 recycle.

Table D-4. Summary of the Efficiency and Cost of Electricity of WRITECoal™ Gasification Scenarios

Parameter	High Temperature Gasifier			Transport Gasifier			Fluidized Bed Gasifier		
	Raw PRB	Partially Dry 6%	W-Coal™	Raw PRB	Partially Dry 18%	W-Coal™	Raw PRB	Partially Dry 20%	W-Coal™
Operating Performance									
Fuel Moisture Content, %	28.35	6.00	0.00	28.35	18.00	0.00	28.35	20.00	0.00
CO_2 Recycle to Gasifier	No	No	Yes	No	No	Yes	No	No	Yes
TOTAL POWER, MWe	589.8	585.7	607.9	645.8	610.1	639.4	605.3	590.4	610.8
Net Power, MWe	371.1	386.8	411.1	468.4	442.6	502.4	430.0	125.1	452.5
Efficiency Increase, %	0.00	2.26	**4.33**	0.00	0.0	**4.81**	0.0	0.10	**3.28**
Costs									
TCR, \$/kW	5,900	5,700	5,300	4,100	4,200	3,500	4,400	4,400	4,100
Capital Costs, mills/kWh	115.00	104.49	**97.58**	41.17	42.10	**35.92**	50.07	49.91	**46.17**
Fixed O&M, mills/kWh	36.35	32.61	30.58	33.49	34.76	29.65	48.19	47.01	49.57
Variable O&M, mills/kWh	20.70	18.93	17.62	17.56	17.55	15.29	19.92	19.76	17.73
Total LCOE, cents/kWh	**17.2**	**15.3**	**14.2**	**9.2**	**9.4**	**8.1**	**11.5**	**11.7**	**11.4**

LCOE – Levelized Cost of Electricity

This corresponds to a lowering of LCOE from 17.2 to 14.2 cents/kWh for the high temperature gasifier, to 11.5 to 11.4 cents/kWh for a fluidized bed gasifier and from 9.2 cents/kWh to 8.1 cents/kWh for the transport gasifier. Part of the difference between the transport gasifier and the fluidized bed gasifier is a result of the higher operating pressure for the transport gasifier.

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Conclusions and Next Steps

It has been demonstrated that the benefits of the WRITECoal™ process on retrofit and new EGUs are:

- Applicable to all low-ranks coals: Powder River Basin subbituminous and Gulf Coast and North Dakota lignites.
- In combustion systems, the WRITECoal™ upgrading technology results a 3-5 % increase in boiler efficiency and a 1-3% increase in net efficiency. A 1% increase in efficiency fleet wide in the U.S. results in 60 million tons of CO_2 emission reduction per year.
- In gasification systems, the integrated WRITECoal™ technology results in 3-5% increase in IGCC cycle efficiency.
- The WRITECoal™ multi-pollutant technology when integrated into an existing subcritical plant results in gaseous emissions reductions (e.g., NOx reductions of up to 40%) and volatile metals reductions (e.g., mercury reductions of 87-92%, arsenic of ~40%-60%, and selenium of ~25%),
- The water in the coal can be recovered and used in the plant, thereby reducing freshwater consumption[4],
- The WRITECoal™ process deployed at the power plant uses waste heat to a large degree, lowering WRITECoal™ energy costs, and
- In both retrofit of the existing fleet and construction of new coal-fired EGUs, the WRITECoal™ integration results in a lower levelized cost of electricity (LCOE), especially when 80-90% carbon capture is required.

As such, the WRITECoal™ process represents one of several important advancements/improvements in gasification for both power generation and chemical production and should be considered as one of the potential enabling technologies that will allow the industry to continue to provide the ratepayers with low-cost, low-greenhouse gas emissions coal-based electrical power. A significant component/process step is that it improves efficiency and costs of retrofitted subcritical air-fired and oxy-fired pulverized coal plants, as well as new IGCC plants each of which may be required to deploy carbon capture in the near future.

As such, WRI has demonstrated that the application pathways for the WRITECoal™- exist for both environmental and COE benefits for existing and new coal-fired plants to the benefit of the industry and the rate payers. The hereto successful research and demonstration results still requires additional support from federal and state governments and industry partners for accelerated large-scale demonstration and deployment of the technology.

Expanding on WRI's WRITECoal™ technology for application as a retrofit to existing plants, a larger-scale utility slipstream demonstration using coal-fired flue gas heating media should be pursued with PRB coal-fired utilities and cogeneration facilities. Specifically, the following recommendations are made.

- A 5 MW_{th} demonstration of the WRITECoal™ gasification/IGCC technology, such as at GTI's U-GAS Flex Fuel facility, is needed to further define and validate the commercial deployment opportunities and cost benefits, or alternatively a5 MW_{th} slipstream unit can be designed and operated at a commercial coal-fired utility site. This scale needs the financial support of the Federal government, State government and coal industry organizations as well as individual utilities.

- And lastly, it is imperative that for advanced coal technologies, such as WRI's WRITECoal™ technology, to be deployed that such deployment not result in New Source Review.

[4] Since the water recovered is free of regulated trace metals and organics and with conventional suspended solids removal, it can be used in the plant without further treatment.

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ATTACHMENT E

In-situ Enhanced Biogenic Methane Production for Increased Coal-Based Gas Production Efficiency

WRI has developed an advanced system for in-situ enhanced biogenic methane production from coal using naturally occurring microorganisms that normally live in coal. This technology extends the life of current coal bed methane wells and allows the revitalization of abandoned, unproductive wells. Additionally, this technology can be used to produce methane from low-rank coal deposits and deposits beyond the reach of financially viable mining. Overall, the enhanced biogenic methane industry is involved in pilot demonstrations internationally but struggling within the United States due to a lack of clear regulations for this industry. Research regarding the environmental impacts, including affects on environmental quality and quality of produced methane, of this technology needs to be completed so appropriate regulations and monitoring practices can be established.

Coal Treatment. The activity of the naturally occurring, methane-producing microbes present in coal can be enhanced in multiple ways. First, coal can be treated to make it a more accessible food source for the microbes, and thus the microbes will produce methane at a faster rate than without the treatment. WRI has data (Figure E-1) showing that this treatment affects the structure of the coal and breaks large carbon compounds into smaller, more easily accessible carbon for the microbes to consume. The smaller compounds, circled in panel B of Figure E-1, are clearly present only after the treatment of coal. It is worth noting that once coal is treated, the treatment does not "spread" beyond the treatment zone. If additional enhanced biogenic methane production is desired, then the in-situ coal conversion zone must be treated again. At this time, it is unknown how the treatment of coal affects metals, such as mercury, that can be trapped within the structure of the coal. Research to understand the effects of coal treatment on potential reduction/avoidance of environmental hazards, such as mercury, arsenic, and other metals, is an essential research area for the establishment of regulations for the enhanced biogenic methane industry.

Nutrient Addition. Nutrients can also be added to stimulate the naturally occurring microbes to consume more coal thereby producing more methane. These nutrients could be found in common food products. WRI has found that addition of nutrients to the naturally occurring microbes in coal can stimulate methane production, but it is a combination of the treatment of coal and addition of nutrients that provides the greatest stimulation of methane production (Figure E-2). When coal is treated and nutrients are added, approximately 20 times more methane was produced in the same amount of time as compared to untreated coal with no added nutrients. Work done by WRI and others has shown that coal can be treated and nutrients added multiple times, and methane production is enhanced with each round of treatment and nutrient addition. The public may be concerned over the release of nutrients into the environment and potentially the water supply. Research regarding the effect of these nutrients on the environment needs to be conducted to understand if then what appropriate level of environmental control and monitoring should be applied.

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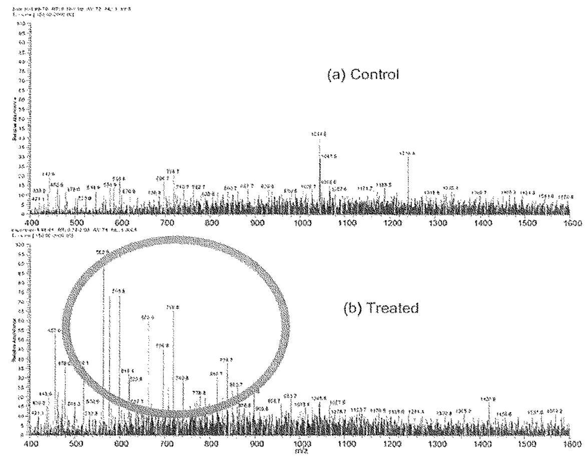

Figure E-1: Negative Ion Electrospray Ionization Mass Spectra of (a) Control and (b) Treated Water-Soluble Fraction in Coal Samples

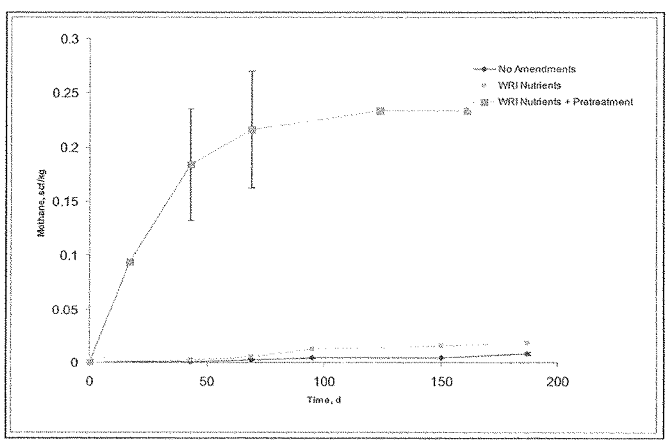

Figure E-2: Methane production was compared from untreated coal, untreated coal with added nutrients, and treated coal with added nutrients. Treatment with nutrients approximately doubled the amount of methane produced when compared to untreated coal with no nutrients. When coal was treated and nutrients were provided, the amount of methane produced was approximately 10 times greater than the amount produced when coal was only treated with nutrients.

Test Sites. United States-based enhanced biogenic methane companies are performing pilot demonstrations of this technology in other countries. A summary of enhanced biogenic methane projects are below, organized by company:

Western Research Institute (WRI). WRI, located in Laramie, Wyoming, partnered with Regal Resources Ltd. of Australia to operate at a pilot scale WRI's enhanced biogenic methane technology [1] . Pictured below in Figure E-3 is WRI's technology deployed at a pilot scale in Australia.

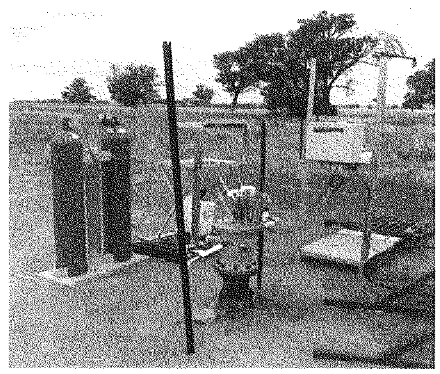

Figure E-3: WRI's pilot scale enhanced biogenic methane technology in Australia.

Ciris Energy. Ciris Energy of Centennial, Colorado has a 160 acre test site and other leases in Wyoming [2]. Ciris Energy has also partnered with Regal Resources Ltd. of Australia for enhanced biogenic methane production in Australia [3]. Recently Ciris Energy announced that it received approximately $25 million from an undisclosed Hong Kong investor for international expansion [3], presumably in Asia.

Luca Technologies. Wyoming was a primary target location for Luca Technologies, located in Golden, Colorado, but the company is now pursuing other locations for their pilot demonstrations after permitting problems in Wyoming.

Next Fuel, Inc. Next Fuel, Inc. located in Sheridan, WY has announced that they are "working on strategic partnership with Australian energy companies to commercialize" their enhanced biogenic methane technology, that they have a pilot scale demonstration in China, and that they have initiated field projects in Indonesia [4]. Next Fuel, Inc. also announced that they "are discussing with a few Canadian resource owners about establishing partnership to commercialize" their enhanced biogenic methane technogy [4]. In 2013, Next Fuel, Inc. announced that it had signed an agreement to conduct a pilot scale project with Vistat Oil-tech Private Ltd. in Gujarat, India [5].

Next Steps: Regulatory issues related to enhanced biogenic methane production in the United States need to be resolved to allow for industry growth and energy production using this technology. To develop meaningful regulations, reliable answers from research are needed. Some research needs to be addressed when developing regulations for this industry include:

- Demonstrations are needed to verify the environmental impacts of this technology are needed to develop reasonable regulations for the enhanced biogenic methane technology. This includes monitoring of water quality, determination of the needed amount and location of monitoring wells, and monitoring of the surrounding coal to verify that this technology does not degrade the quality of that coal for mining.
- The regulatory agency that regulates the enhanced biogenic methane industry needs to be determined, since it is currently unclear whether it should be regulated with coal and natural gas or if it should be regulated by an environmental agency.
- The United States should examine regulations for enhanced biogenic methane production in countries that are using this technology.
- The owner of the mineral rights to methane produced from coal needs to be established. It is currently unclear if the person/entity that owns the mineral rights for the coal also owns the right for the in-situ methane produced from that coal or if it is a different mineral right since the resource being collected is methane.

References:

1. Fugleberg, J., *Wyoming researchers license new methane process*, in *Casper Star Tribune*. 2011: Casper.
2. *Ciris Forms Wholly Owned Australian Subsidiary*. 2012 [cited 2013 July 16]; Available from: http://cirisenergy.com/news/announcements/ciris-forms-wholly-owned-australian-subsidiary/.
3. Herndon, A. *Hong Kong Investor Backs Ciris's Microbial Coal-to-Gas Process*. 2013 [cited 2013 July 16]; Available from: http://www.businessweek.com/news/2013-02-28/hong-kong-investor-backs-ciris-s-microbial-coal-to-gas-process.
4. *Next Fuel, Inc: Global Reach*. 2013 [cited 2013 July 16]; Available from: http://www.next-fuel.com/worldwide.
5. *Next Fuel Inc Signs Agreement To Conduct Coal-to-Gas Operations In India*. July 17, 2013; December 20, 2012:[Available from: http://www.reuters.com/finance/stocks/NXFI.PK/key-developments/article/2663850.

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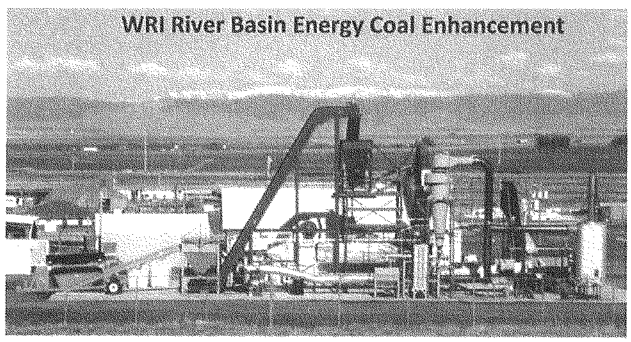
ATTACHMENT F

Coal Dryer Energy Enhancer: Delivering Cleaner, Higher Energy, Lower Emission Low-Rank Coal

Benefits:

- ✓ Upgrades PRB coal energy value from 8,000 to 10,500-11,000 Btu/lb
- ✓ Removes ~85% of mercury and 40-60% of arsenic and selenium delivering a cleaner coal
- ✓ Low mercury coal lessens mercury capture retrofit and operational expense
- ✓ Clean Wyoming coal export lowers emissions in other countries that don't install emission controls. **Note**: More mercury lands in the U.S. each year from foreign country sources.
- ✓ Export sale enables achieving U.S. domestic mercury reduction policy goals.
- ✓ Inherently stable against spontaneous combustion without need for coating
- ✓ Increases sale price of low-rank coal ($9-11/ton) comparable to eastern coals: $30 - 50/ton
- ✓ Energy-Water Nexus: Produced water is non-toxic and is usable for Clean Air Act dust suppression at mine sites



Summary:

- WRI successfully developed a coal upgrading technology which increases marketability and environmental performance of low rank coals.
- The technology increases heating value, reduces moisture content, and reduces mercury, arsenic and sulfur constituents to allow for large scale use by coal consumers.
- Successfully designed and operated a patented process for coal upgrading, at a scale of ~100 tons/day, delivering a value-enhanced cleaner coal for power and heat generation.
- Reduces carbon footprint and other emissions while increasing energy efficiencies.
- Technology addresses energy-water nexus as the water discharge is clean and usable as-is for dust management to meet Clean Air Act dust management requirements.

Next Steps: Plans are under development to deploy the technology in Gillette, Campbell County, Wyoming. This first commercial plant for upgrading the energy (Btu) value of low rank

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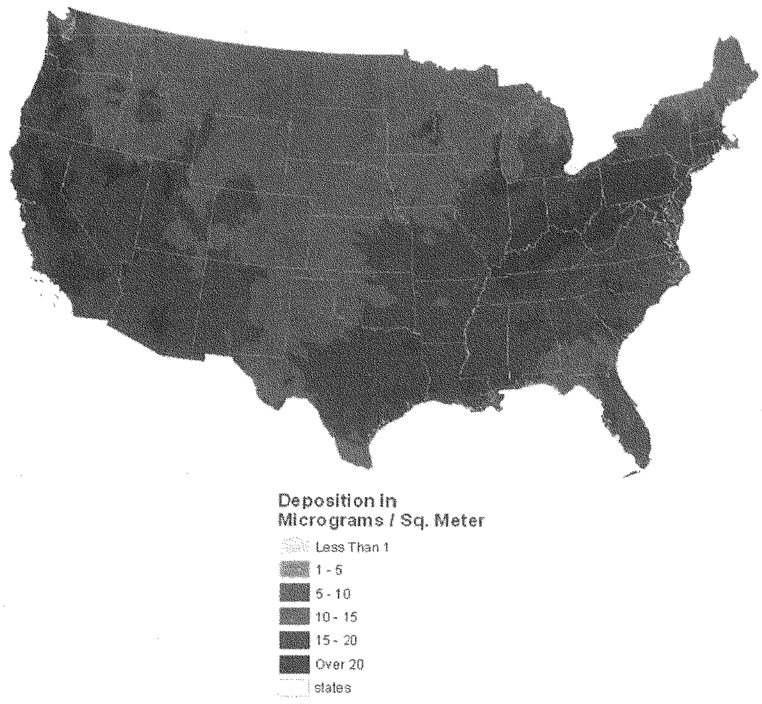
coal will remove 85% of the mercury from PRB coal will deliver the cleanest coal available in the world. The project is expected to create 20 jobs during the construction phase and 30 jobs during operations of the first plant. The project is expected to bring up to $50 million to the State of Wyoming during construction and job wages of $2.3 million per year during operations.

The figure below illustrates the high mercury areas within the U.S. High levels exist in the west coast states. The source for the figure is from the U.S. EPA 2005 Community Multiscale Air Quality Model. Presently, a large percentage of mercury depositing in the west coast states is attributable to coal burning power plants in China. The amount of mercury depositing in these states is expected to increase over the next few decades due in large part to predicted large growth in coal burning plants in China. The Wyoming technology described above provides a means to remove nearly all mercury from Wyoming coal that is exported to Asian markets, including China. This provides an U.S. developed technological solution to protect western states from growth in future mercury deposits while dealing with the practical reality of environmental policies in China and other Asian countries – a win for Wyoming and a win for California.



Don Collins

Don Collins is the Chief Executive Officer of Western Research Institute located in Laramie, Wyoming. He and his team focus on transitioning scientific and applied research into technologies for clean zero-emission energy, environmental emissions capture, in-situ environmental remediation, water conservation and reuse, and lower cost methods for building highways.

He has 29-years of experience in engineering and management of research, design, and deployment of new technologies.

Prior to arriving at WRI, Don managed groups of scientific and engineering project managers in pursuit of the U.S. Department of Energy Clean Coal Technology RDD&D goals. For about 6.5-years he managed DOE RDD&D programs focused on fuel cells and energy storage technology for distributed and central power applications, including smart grid technologies. In this role, he was responsible for hydrogen turbines and high efficient CO_2 compressor development under the DOE's FutureGen and Carbon Sequestration programs.

Don's first 17-years were dedicated to submarine technologies and integration of complex systems for SEAWOLF and VIRGINIA Class submarines, for the U.S. Navy, including CO2 scrubber technology.

Chairman LUMMIS. Thank you, Mr. Collins.

And now I recognize Ms. Greenwald to present her testimony. Good morning.

TESTIMONY OF MS. JUDI GREENWALD, VICE PRESIDENT, CENTER FOR CLIMATE AND ENERGY SOLUTIONS

Ms. GREENWALD. Thank you. Madam Chairman, Congressman Swalwell, and Members of the Subcommittee, thank you for the opportunity to testify, and thank you, Congressman Veasey, for that kind introduction.

My name is Judi Greenwald, and I am the Vice President for Technology and Innovation at the Center for Climate and Energy Solutions. My testimony today will focus on the most important climate and energy solution that no one knows about. I will emphasize two main points.

First, carbon capture and storage, or CCS, is a critical technology for addressing climate change while allowing continued reliance on fossil fuels. Second, carbon dioxide-enhanced oil recovery, or CO_2 EOR, can advance CCS while boosting domestic oil production and creating and generating that Federal revenue.

The United States and the rest of the world get 80 percent of our energy from coal, oil and gas, and our fossil fuel dependence is expected to continue for the foreseeable future. Carbon dioxide emissions from burning these fuels pose an enormous challenge. That is why we need CCS, a suite of technologies that capture CO_2 and stores it deep underground in geological formations. CCS can capture up to 90 percent of emissions from power plant and industrial facilities, allowing coal and natural gas to remain part of our energy mix. CCS has been commercialized for certain industrial processes. However, CCS in other contexts, for example, coal and natural gas power plants is a relatively expensive technology that is just reaching maturity. The key challenge for CCS is to get a sufficient number of commercial-scale projects up and running to demonstrate the emerging technologies at scale and bring down their costs.

The Department of Energy's role in CCS development has been and will remain critical. DOE is working with the private sector on the leading innovative CCS projects today including several coal-based power projects. Additional drivers will be needed, though, to help the next generation of CCS projects move forward. That is why CCS is being increasingly thought of as carbon capture utilization and storage, or CCUS.

Utilizing captured carbon dioxide for enhanced oil recovery, or CO_2 EOR, could play a key role in the development of CCS. It also has the potential to increase American oil production by tens of billions of barrels while displacing imported oil and safely storing billions of tons of carbon emissions underground.

Let me explain how this works. Even after conventional primary and secondary oil recovery, most of the oil in a typical field is left in the ground. Injecting carbon dioxide deep underground can make it possible to recover more oil and extend the field's life. The United States has been a global leader in CO_2 EOR for 40 years, and gets six percent of its domestic oil this way. While most CO_2 EOR activities occur in the Permian Basin of Texas, there are also projects in Wyoming, the Gulf Coast, Oklahoma and Michigan. Using existing technologies, CO_2 EOR could double or triple U.S. reserves. It could also store 10 to 20 billion tons of carbon dioxide, equivalent to five to ten years. worth of emissions from all U.S. coal-fired power plants. More advanced technologies could yield much higher production and CO_2 storage.

Right now, most enhanced oil recovery is done using carbon dioxide that is already underground and that is ironically in short supply. By using captured manmade carbon dioxide, we can increase domestic oil production, promote economic development, create jobs, reduce carbon emissions, and drive innovation in CCS technology. Because of these multiple benefits, we have been able to bring together the National Enhanced Oil Recovery Initiative, or NEORI, a diverse coalition of industry, labor and environmental organization, and state officials. This coalition's consensus recommendations call for a Federal tax incentive to capture manmade CO_2 for EOR.

In some regions, EOR operators are willing to pay upwards of $30 per ton for CO_2. At the same time, industrial facilities and power plants are emitting billions of tons of CO_2 into the atmosphere as a waste. CO_2 EOR offers the opportunity to transform this waste into a marketable commodity and transform an environmental problem into an energy production solution. By combining private EOR operators willing to pay for CO_2 with a tax incentive, society would leverage its public investment. Tax incentives for carbon dioxide-enhanced oil recovery would more than pay for themselves within ten years by increasing domestic oil production and associated taxable oil revenues. Federal revenue would exceed the fiscal cost of new incentives by more than $100 billion over 40 years.

To summarize, CCS is a critical technology for reconciling our continued dependence on fossil fuels with the imperative to protect the global climate. Our best hope at the moment for advancing CCS is carbon capture utilization and storage, or CCUS, and the best current example of that is enhanced oil recovery. Solving our climate and energy problems will require a portfolio of technologies, and all must be pursued vigorously. But we are focusing here today on CO_2 EOR because it is the most important climate and energy solution that no one knows about.

Thank you for your attention. I look forward to your questions and to working with the Subcommittee and the Congress to advance this critical technology.

[The prepared statement of Ms. Greenwald follows:]

Testimony of

Judi Greenwald
Vice President for Technology and Innovation
Center for Climate and Energy Solutions

before the

Subcommittee on Energy
Committee on Science, Space, and Technology
U.S. House of Representatives

Hearing on The Future of Coal: Utilizing America's Abundant Energy Resources

July 25, 2013

Carbon Capture, Utilization and Storage

Madam Chairman, Rep. Swalwell, and members of the Subcommittee, thank you for the opportunity to testify on carbon capture, utilization, and storage. My name is Judi Greenwald, and I am Vice President for Technology and Innovation at the Center for Climate and Energy Solutions (C2ES – formerly known as the Pew Center on Global Climate Change).

My testimony today will focus on the most important climate and energy solution that no one knows about. I will emphasize two main points:

- Carbon capture and storage (CCS) is a critical technology for solving climate change, while allowing continued reliance on fossil fuels.

- Carbon dioxide enhanced oil recovery (CO_2-EOR) can advance CCS, while boosting domestic oil production and generating net federal revenue.

C2ES is an independent, nonprofit, nonpartisan organization dedicated to advancing practical and effective policies and actions to address our global climate change and energy challenges. We perform multifaceted research and analysis of the scientific, technological, economic, and policy aspects of these issues. Our work is informed by our Business Environmental Leadership Council (BELC), a group of 34 major companies, most in the Fortune 500, that work with C2ES on climate change and energy risks, challenges, and solutions. The views I am expressing, however, are those of C2ES alone.

C2ES has been analyzing CCS for over a decade and has recently focused on how CO_2-EOR can advance CCS. With the Great Plains Institute, C2ES co-convenes the National Enhanced Oil Recovery Initiative, or NEORI, a coalition of businesses, environmental NGOs, labor representatives, and state officials advocating for incentives to use captured CO_2 in EOR. You can find more information on NEORI at www.neori.org. I would like to submit NEORI's CO_2-EOR analysis and consensus recommendations for the record. In addition, C2ES serves as the advisor and facilitator to the Sequestration Working Group of the North America 2050 Initiative, a collaborative of states and provinces exploring options for CCS regulations and incentives. C2ES recently completed a summary of state-level regulations and incentives that can be found at www.na2050.org/sequestration.[1]

C2ES also has authored research and publications related to CCS and CO_2-EOR. For example, C2ES developed a comprehensive framework for calculating CO_2 emissions from CCS based on input from experts in industry, academia, and the environmental community.[2] C2ES also publishes a CCS Climate TechBook,[3] a brief report that explains in layman's terms how CCS technology works, why its development is needed to address climate change, and how it might be advanced.

CCS is a critically important technology

The United States and the rest of the world are getting 80 percent of our energy from coal, oil and gas, and our dependence on, and overall use of, these fossil fuels globally is growing rapidly. Under a business-as-usual scenario, the Energy Information Administration expects fossil fuels will continue to provide more than 65 percent of U.S. electricity in 2040 – with 35 percent coming from coal-fired generation. Globally, coal consumption is expected to increase nearly 60 percent over the next two decades, led by developing countries like China and India, which together will comprise 62 percent of the total global coal demand in 2035. This poses an enormous challenge, because the CO_2 emissions from the combustion of these fossil fuels are the major contributor to global climate change. While we can and should become more energy-efficient and shift our energy mix toward inherently zero-emitting sources like nuclear power and renewables, it will be difficult to do that fast enough and at a reasonable enough cost to avoid the worst climate impacts.

Hence the critical need for CCS, a suite of technologies that captures CO_2 and stores it deep underground in geological formations. CCS can capture up to 90 percent of emissions from stationary sources, such as power plants and industrial facilities, thereby allowing coal and natural gas to remain part of our energy mix. The International Energy Agency (IEA) and others have demonstrated through detailed technology and economic scenario analyses that CCS is likely an essential component of an affordable and effective response to global climate change. In fact, IEA estimates that CCS could provide one-sixth of the requisite GHG emissions reductions by 2050.

What is needed to advance CCS?

CCS has been established and commercialized for the capture of CO_2 from some industrial processes such as natural gas processing, chemical, fertilizer and ethanol production, and the

[1] http://na2050.org/wp-content/uploads/2013/07/NA2050_State_Policy_Actions_to_Overcome_Barriers_to_CCS_and_CO2-EOR.pdf
[2] http://www.c2es.org/publications/greenhouse-gas-accounting-framework-carbon-capture-and-storage-projects
[3] http://www.c2es.org/technology/factsheet/CCS

gasification of coal. The use of man-made CO_2 in EOR has been practiced for several decades. However, CCS in other contexts – for example, coal- and natural gas-powered electricity generation – is a relatively expensive technology that is just reaching maturity. Further R&D is important, but the key challenge for CCS is to get a sufficient number of commercial-scale projects up and running to demonstrate the emerging technologies at scale and bring down their costs. The first large-scale commercial CCS power projects are under construction. Yet, it is still unclear whether more commercial-scale CCS projects will be built after these initial projects are completed. After the collapse of climate legislation in the United States in 2010, a number of CCS projects were cancelled.

CCS is being increasingly thought of as carbon capture utilization and storage, or CCUS. Instead of seeing CO_2 as a waste, utilizing and selling captured CO_2, primarily for EOR, improves the economics of CCS projects and is an important market driver. Almost all of the existing or planned CO_2 capture projects in the United States have been developed with the intention of marketing captured CO_2 for use in EOR. Still, in many cases, additional drivers are needed. Those projects operating or underway today are being financed though some combination of U.S. Department of Energy (DOE) grants, utility cost recovery from ratepayers, private finance, sales of CO_2 for EOR, other revenue streams from chemical production, and existing tax credits.

DOE's role in CCS development has been and will remain critical. DOE is working with the private sector on the leading innovative CCS projects in the United States today. This collaboration is beginning to yield results. In late 2012, the DOE-supported Air Products' Port Arthur CCS project, where CO_2 is captured from refinery-based hydrogen production and sent for use in EOR, began operations. Through its Industrial Carbon Capture and Storage (ICCS) Program and with funding from the American Recovery and Reinvestment Act of 2009 (ARRA), DOE agreed to fund $284 million of the Port Arthur project's $430 million total investment cost. The Port Arthur project is expected to capture up to 1 million tons of CO_2 per year and enable EOR production of 1.6 million to 3.1 million barrels of domestic oil a year in East Texas.

DOE is also working on applying CCS to the power sector. Southern Company's coal-fueled Kemper County energy facility in Mississippi is now under construction and will be the first commercial-scale CCS power project in the United States. DOE selected the Kemper project to receive more than $290 million through its Clean Coal Power Initiative (CCPI). A later round of the CCPI made possible through ARRA funding selected three additional coal-fired CCS power projects for funding. They are Summit Power's Texas Clean Energy Project (TCEP), NRG Energy's Washington Parish Project, and SCS Energy's Hydrogen Energy California project. TCEP is nearing financial close and, when completed, will capture 90 percent of its emissions and supply approximately 2.5 million tons of CO_2 for use in EOR.

Given the high costs and uncertainties of CCS investment for the private sector and the urgent need for CCS, it is extremely important that the federal government continue to support CCS research, development, demonstration, and deployment. Beyond DOE's pivotal role, other forms of federal financial support, such as tax credits, should be reformed and expanded. States too can play a key role in advancing CCS through incentives and well-informed regulation.

Background on CO_2-EOR

CO_2-EOR is a means of commercial oil production that could play a key role in the development of CCS and in increasing our domestic energy security. CO_2-EOR has the potential to increase American oil production by tens of billions of barrels, while displacing imported oil and safely storing billions of tons of CO_2 underground.

How does CO_2-EOR work? Even after conventional primary and secondary oil recovery, most of the oil in a typical oil field is left in the ground. When injected deep underground, CO_2 can make it possible to recover more oil and extend an oil field's life. The best available evidence indicates that by using best EOR industry practice and existing rules governing underground injection, the overwhelming majority of the injected CO_2 remains underground, incidentally and safely storing CO_2. Commercial injection of CO_2 for EOR is regulated under EPA's Underground Injection Control Program, and under current federal greenhouse gas reporting rules for air emissions, EOR operators may document this incidental CO_2 storage through additional monitoring, reporting, and verification requirements to qualify as geologic sequestration. There is a range of views as to what additional state or federal rules are needed to ensure that CO_2 is stored permanently.

The United States has been a global leader in CO_2-EOR for 40 years. We currently obtain six percent of our domestic oil production through this method. While most CO_2-EOR activity occurs in the Permian Basin of Texas, there are also projects in the Gulf Coast, the Rocky Mountains, Oklahoma, and even Michigan. Estimates of the potential for CO_2-EOR to increase oil production and store CO_2 have been increasing in recent years. According to the National Energy Technology Lab, using existing techniques, CO_2-EOR could double or triple U.S. oil reserves and store 10 to 20 billion tons of CO_2, which is equivalent to between five and 10 years of emissions from all U.S. coal-fired power plants. More advanced techniques could yield much higher oil production and CO_2 storage.

The key role of CO_2-EOR in advancing CCS

For those CO_2 capture technologies that have not reached full commercialization, especially in electric power generation, selling captured CO_2 for use in EOR can provide a revenue stream that helps reduce the financial risks and uncertainty of investing in emerging technology. About 75 percent of the CO_2 used in EOR currently comes from naturally occurring CO_2 reservoirs. The rest comes from man-made CO_2 sources. Somewhat oddly, the EOR market lacks sufficient CO_2. By expanding carbon capture from man-made sources, we can increase domestic oil production, promote economic development, create jobs, reduce CO_2 emissions, and drive innovation in CCS technology.

It is because of these multiple benefits that we have been able to bring together the National Enhanced Oil Recovery Initiative, or NEORI, a diverse coalition favoring the reform and expansion of existing tax incentives to use captured CO_2 in EOR. Among the members of NEORI are Arch Coal, Summit Power, Tenaska, the Natural Resources Defense Council, AFL-CIO, and The Wyoming Outdoor Council. Some of NEORI's participants are primarily interested in job creation, others in increasing domestic oil production, and others in protecting the environment. But all agree that advancing the capture of man-made CO_2 for use in EOR makes sense. NEORI has been briefing members on both sides of the aisle in both houses of Congress on its proposals.

EOR operators in some regions are willing to pay upwards of $30 per ton for CO_2. At the same time, industrial facilities and power plants are emitting billions of tons of CO_2 into the atmosphere as a waste. CO_2-EOR therefore offers the opportunity to transform this waste into a marketable commodity and transform an environmental problem into an energy production solution.

In a few cases, revenue from selling CO_2 for enhanced oil recovery is sufficient to pay for CO_2 capture and transport. Thanks to the efforts of the private sector and DOE, many CO_2 capture technologies are already commercially proven, and only a modest incentive is needed to help close the gap between the market price of CO_2 and the costs to capture and transport it. In the case of emerging technologies, however, companies need a larger incentive to help shoulder the additional financial and operational risk of deploying new, pioneering capture projects for the first few times at a commercial scale.

By combining private EOR operators' willingness to pay for CO_2 with a tax incentive, society leverages its public investment. Perhaps most importantly, according to our analysis, such tax incentives would more than pay for themselves by driving increased domestic oil production and associated taxable oil revenues. Increased CO_2-EOR production will generate federal revenue that more than pays for the cost of new incentives within a 10-year timeframe. Under existing tax treatment, CO_2-EOR directly yields revenues from three main sources: corporate income taxes, individual income taxes on royalties from production on private land, and royalties from production on federal land. Our analysis indicates that federal revenues from incremental CO_2-EOR production would exceed the fiscal cost of new incentives by more than $100 billion over 40 years.

Conclusion

CCS is a critical technology for reconciling our continued dependence on fossil fuels with the imperative to protect the global climate. Our best hope at the moment for CCS advancement is carbon capture, *utilization*, and storage, or CCUS. The best example of CO_2 utilization we know of is enhanced oil recovery (CO_2-EOR). Solving our climate and energy problems will require a portfolio of technologies, and all must be pursued vigorously. But we are focusing here today on CO_2-EOR, because it is the most important climate and energy solution that no one knows about.

CENTER FOR CLIMATE AND ENERGY SOLUTIONS

Judi Greenwald, Vice President, Technology and Innovation

Judi Greenwald is the Vice President for Technology and Innovation at the Center for Climate and Energy Solutions. She oversees the analysis and promotion of innovation in the major sectors that contribute to climate change, including transportation, electric power, buildings, and industry. Ms. Greenwald focuses on technology, business, state, regional, and federal innovation. She is a member of the Advisory Council of the Electric Power Research Institute and served on several National Academy of Sciences panels studying vehicles and fuels. She also served on the Resource Panel for the northeast Greenhouse Gas Initiative and the California Market Advisory Committee, and as a policy advisor to the Western Climate Initiative and the Midwest Greenhouse Gas Accord Advisory Group. She was previously the Vice President for Innovative Solutions at the Pew Center on Global Climate Change, C2ES's predecessor organization.

Ms. Greenwald has over 30 years of experience working on energy and environmental policy. Prior to coming to the Pew Center, she worked as a consultant, focusing on innovative approaches to solving environmental problems, including climate change. She also served as a senior advisor on the White House Climate Change Task Force. As a member of the professional staff of the U.S. Congress Energy and Commerce Committee, she worked on the 1990 Clean Air Act Amendments, the 1992 Energy Policy Act, and a number of other energy and environmental statutes. She was also a Congressional Fellow with then-Senate Majority Leader Robert C. Byrd, an environmental scientist with the U.S. Nuclear Regulatory Commission, and an environmental engineer and policy analyst at the Environmental Protection Agency.

Ms. Greenwald has a Bachelor of Science in Engineering, cum laude, from Princeton University, and an M.A. in Science, Technology and Public Policy from George Washington University

Chairman LUMMIS. Thank you, Ms. Greenwald, and thank you, panel.

Now, if we would limit our questions to four minutes each, we could probably—everybody in this room could get to ask questions before our vote series. If there is no objection to going with four minutes instead of five, then so ordered, and we will start—the Chair now recognizes herself for four minutes. Thank you, panel, for being here. I am going to start with Mr. Collins.

In your testimony, you talked about integrated portfolio approaches to maximize benefits of coal. Could you tell us which of those technologies you believe are the most promising to improve energy utilization?

Mr. COLLINS. Yes, Madam Chairman. We have a process called WRITECoal that will extract the water out of low-rank coals that in the past has really been a missed opportunity. Low-rank coal, especially out of Wyoming, has been beneficial for reducing sulfur emissions because of its low sulfur content, and the water has just gone up the smokestack along with other emissions. By extracting that water at the front end, we can utilize that water in the power plant and reduce local water consumption in communities that are water stressed by about 50 to 60 percent for the makeup water, especially in air-cooled systems. So we see that as a second value of low-rank coals that were delivering water with the energy resource.

A second technology is a chemoautotrophic bacterial process that will operate in the dark 24 hours a day to consume CO_2 and make a bio crude oil that can be used to make synthetic diesel fuel, for instance, and perhaps even other longer-chain carbon molecules like biopharmaceuticals and turn that carbon in our coal into an additional economic resource by using it more than once, and that is our view to look at recycling energy.

Chairman LUMMIS. Thank you, Mr. Collins.

Now, Mr. Yamagata and Ms. Greenwald, I have a question about the fossil energy loan guarantees, and they were—monies were directed under the Energy Policy Act of 2005 to advance technologies and facilitate commercial application. Four projects were selected for further evaluation in July of 2009, and to date, no final loan guarantees have been issued. Your groups have focused in part on these loan guarantees and their status. To your knowledge, where are they in the DOE process? Mr. Yamagata, any response there?

Mr. YAMAGATA. Madam Chair, frankly, I don't know where they are. We know that the process that was started several years ago in which DOE actually accepted—because that is the process, the applications—and the DOE at least as we understand it, the Secretary or his designee can stop that process at any point in time but we don't know that that has ever happened with respect to those four projects. So the answer at least in short is, we are not quite certain where those projects are. They don't appear to have been rejected.

Chairman LUMMIS. Ms. Greenwald, do you know?

Ms. GREENWALD. We don't know either.

Chairman LUMMIS. Thank you.

Mr. Smith, I might ask, has DOE taken any steps to advance these projects?

Mr. SMITH. Thank you for the question, Madam Chairwoman. So I manage the Office of Fossil Energy, which oversees all the research and development that is done to advance fossil energy technologies. I don't have oversight over the loan guarantee program. I do know that the projects that were selected in that first round focused primarily on CTL technologies. We have recently announced an additional level of funding of $8 billion, which is another series of potential loan guarantees that would have a very wide range of applications for fossil energy technologies. We have taken the unprecedented step of offering that for public comment so we can get feedback back from industry, back from states, back from key stakeholders so that we can structure that in a way that has the highest probability of attracting the right type of participants and make sure that we are successful moving that forward. So that is the process that we are pushing for in real time right now.

Chairman LUMMIS. Thank you, panel.

And now I yield four minutes to the Ranking Member, Mr. Swalwell.

Mr. SWALWELL. Thank you, Madam Chair.

For our witnesses, it is pretty evident now after a number of scientific studies that 97 percent of scientists agree that human activities are causing climate change, and so I want to ask each one of you whether you agree or disagree with the 97 percent of scientists who believe in that.

Mr. Smith, do you agree or disagree?

Mr. SMITH. We agree that most of our programs are focused very strictly on reducing CO_2 emissions and greenhouse gas emissions.

Mr. SWALWELL. But do you agree that climate change is caused by human activities?

Mr. SMITH. We do agree that this is something we need to address, so we agree.

Mr. SWALWELL. Mr. Yamagata, agree or disagree?

Mr. YAMAGATA. You are not going to like this answer. We don't——

Mr. SWALWELL. Is it agree or disagree?

Mr. YAMAGATA. We don't take a position on that issue. It is not something that we want to deal with. What we want to deal with is if public policy determines that this is an issue, we have got to have the technologies available to address it.

Mr. SWALWELL. How about you personally, Mr. Yamagata? Do you agree or disagree?

Mr. YAMAGATA. I think there is a lot of information out there that suggests so.

Mr. SWALWELL. Mr. Collins, do you agree or disagree?

Mr. COLLINS. Thank you, Congressman Swalwell. I would say you probably won't like my answer either. There are multiple contributions to what people consider climate change, and it is not all just man made anthropogenic sources. So that statement, in my mind, is incomplete, so that is why I cannot agree to the question.

Mr. SWALWELL. Do you agree that human activity has played a role, a substantial role, in climate change?

Mr. COLLINS. Human activity releases a lot of energy into the environment that contributes to the warming, but I also view that

CO_2 is an untapped resource and we need to start thinking about how we utilize that. We live in a carbon-rich world. You and I are carbon-based life forms. To consider living in a carbon-free world to me sounds like suicide.

Mr. SWALWELL. And Ms. Greenwald, do you agree or agree with the 97 percent?

Ms. GREENWALD. We agree. I focus on the technology solution side of our organization but we do have staff that focuses on science, and we do work in that area and do agree with the scientific consensus.

Mr. SWALWELL. Great. Thanks, Ms. Greenwald.

Mr. Smith, over the history of research to reduce the environmental impacts of coal-fired power plants and to improve their efficiency, where has the bulk of the innovation taken place? Has that been in the private sector or has it been at the national laboratories or our research universities?

Mr. SMITH. Well, thank you for the question, and without making a direct comparison, I would say that this is an area in which it is critical for the government to be involved. We work very closely with private industry in all the major demonstrations that we are pushing out. We need to ensure that we have got scientists that work in national laboratories working alongside the practitioners in the field in industry, so that is always going to be a collaborative effort. That is the only way to move forward.

Mr. SWALWELL. And have Federal regulations played a role in incentivizing these innovations, and if so, how?

Mr. SMITH. Well, first of all, I think it is important that we fund critical programs that allow us to do this work. If you look at the investments that we have made since the start of this Administration, we have made a significant investment in major demonstrations that came from the Recovery Act, and in every year of the President's budget over the last several years, we have made important, significant investments in carbon capture and sequestration that fund that government programs and allow us to work together with industry.

Mr. SWALWELL. Great, and I will yield back in the interest of allowing more questions from our colleagues.

Chairman LUMMIS. I thank the gentleman. I now yield to the gentleman from Texas, Mr. Neugebauer, for four minutes.

Mr. NEUGEBAUER. Well, Madam Chairman, thank you for holding this important hearing.

Mr. Smith, the Environmental Protection Agency is moving forward with greenhouse gas regulations on both new and existing coal-fired plants. In EPA's initial regulatory proposal for new plants released last year, the EPA rulemaking assumed that CCS technology would be commercially available within ten years of plant initiating operations. Do you agree that with this new proposed rule, which I understand is now under revision, would have basically effectively banned the construction of new coal plants without CCS?

Mr. SMITH. Well, thank you for the question, Congressman. I can't comment on the rule as it has not yet been published. It is in interagency review at the moment, and that is a process that is being managed centrally. What I can say is that the Department of Energy has an important role to play in terms of shaping that rule, and we believe it is critically important that we are working together with EPA and that we are working together with industry to ensure that these technologies are commercially ready, that they are being developed, that we are making the right investments, and that these innovations are created here in the United States so that we are creating that opportunity here for our country. So that is the role that the Department of Energy plays in that process.

Mr. NEUGEBAUER. Well, along those same lines, though, then would you agree that in order for CCS to be a part of the new coal plant that significant technical, legal, property rights and liability issues will have to be resolved?

Mr. SMITH. Congressman, I agree that there are myriad issues that need to be resolved, and that is the process that we are in real time going through. This is an important innovation that will allow us to achieve this mission.

Mr. NEUGEBAUER. So then with that in mind, what is the earliest time frame in which you can state with confidence that CCS will be commercially available for utility scale?

Mr. SMITH. Well, Mr. Congressman, I would state that currently, we know an awful lot about how to capture CO_2 and we know an awful lot about storing it. The work that we are going through right now is to ensure that we are continuing to push these costs down and that we are making it more and more affordable for broad-scale release. So I can't make a projection in terms of what exactly that cost curve is going to look like, but that is the process of innovation that we are going through now and we are making important strides in real time in that mission.

Mr. NEUGEBAUER. So I guess the question goes back to kind of where I started. If we can't get to that point, are we basically keeping new power plants from being brought online and potentially closing existing ones? The chairwoman mentioned some statistics of how many plants had been closed, so the vagueness of your answer leads me to believe that you are not sure whether this technology will be in place and that in fact would preclude bringing those plants online, wouldn't it?

Mr. SMITH. Well, coal is under stress from a number of factors including the emergence of natural gas that has pushed natural gas prices down, and natural gas has leapfrogged coal in a lot of areas in terms of how coal power plants get dispatched. That is a challenge, and it makes it difficult for these plants to move forward. What we are working on is making sure that we are not only focused on CCS, carbon capture and sequestration, and lowering those costs, but we are also working with industry to improve efficiencies, to improve processes, better sensors, better materials, to ensure that this important part of our energy mix continues to contribute to energy security in the future. It is—this is research activity. These are technological innovations. They don't have certainty, just as any research topic tends not to, but we are making investments to ensure that we are moving that forward and we do have high levels of confidence.

Mr. NEUGEBAUER. So would this be a true statement, that this Administration is not a big fan of coal?

Mr. SMITH. I would say that is categorically not a true statement. I mean, if you look at the investment that we have made since this Administration started, almost $6 billion invested in CCS technologies, greater efficiencies, better materials, better processes, more efficient turbines. These are all investments that we have made to ensure that this important source of domestic energy—coal—continues to be part of the clean energy economy of the future. So when we say all of the above, I mean, that is not a slogan. It is an investment this Administration has made over the past four years. So I actually would not agree with that comment, respectfully, Mr. Congressman.

Chairman LUMMIS. I thank the gentleman from Texas and yield to another gentleman from Texas, Mr. Veasey, and it is Veasey, isn't it?

Mr. VEASEY. That is correct, Madam Chair.

Chairman LUMMIS. You know, I had tee shirts made for my second campaign that said "Lummis rhymes with hummus" on them just because I got it to so much, so I suggest the tee shirt route, Mr. Veasey.

Mr. VEASEY. Yes.

Chairman LUMMIS. The gentleman is recognized for four minutes.

Mr. VEASEY. I have done "Veasey is easy" before.

And I wanted to ask Ms. Greenwald specifically if she could tell me a little bit more about her organization's work with important carbon capture and storage and reuse projects in Port Arthur as well as Pinwale, and for those of you that aren't from Texas, Port Arthur is a very important geographic area as it relates to energy and——

Mr. WEBER. And represented by the greatest Congressman in the world, I am just saying.

Mr. VEASEY. That would be Mr. Weber.

Ms. Greenwald, please.

Ms. GREENWALD. Well, I am glad to talk about projects that are near and dear to both of your hearts. We were actually just in Port Arthur recently. We had a workshop for state and provincial officials from both the United States and Canada talking about CO_2 EOR and its relationship to carbon capture and storage, and while we were there we did a site visit to the Air Products facility in Port Arthur, Texas, and that is a hydrogen production facility that is doing carbon capture, and they are using their CO_2. They are sending it into a pipeline to be used for CO_2 EOR. So it is a classic example of the kind of project that is really making a difference, moving ahead on carbon capture and also advancing our increasing U.S. oil production. So it is a great project. It is also getting DOE funding, so it is a huge DOE success as well. And so that has been a great project, and it just got up and running a few short months ago, and Air Products is also a member of our National Enhanced Oil Recovery Initiative group, and so they have been active in that as well.

Mr. VEASEY. Good, good. Let me ask you about CCS, and, you know, how would you compare the need to support CCS with the need to support other energy sources such as renewable energy or nuclear power? And I think particularly with renewable energy and that support going hand and hand because it is something that we really don't, you know, talk about enough, and if we want to have a serious all-of-the-above approach, I think that we obviously need to.

Ms. GREENWALD. You know, the way we think about this is, we think about a strategy. We might say all-of-the-above clean. We basically think that all of these technologies—nuclear power, renewables, efficiency, carbon capture and storage with gas or coal—all of the most promising technologies we should be working on both in the R&D level but also in deployment and encouraging them to be used more in the marketplace. So we recommend that we pursue a portfolio approach and make sure that we have a range of technologies that are available. For us, it is all about performance. If any particular fuel or technology can give the environmental performance that we need and the energy security benefits that we need, that is what we want to achieve. So we don't come out and say this is the best technology.

As I said in my testimony, though, the reason we have been focusing on CO_2 EOR today and recently is that that is an example of a solution that a lot of people just don't know about, but we do support looking all across the board and making sure that we are placing bets on the most promising technologies so that they will be available for broader use in the marketplace and encouraging the use of the cleanest and most energy beneficial projects in the marketplace.

Mr. VEASEY. Thank you, Ms. Greenwald. I appreciate you answering those questions and I appreciate your work on these important energy and environmental issues. Thank you very much.

Madam, I yield back the balance.

Chairman LUMMIS. Thank you, Mr. Veasey, and the chair now recognizes the gentleman from Kentucky, Mr. Massey.

Mr. MASSEY. Before I ask my question, I just want to say that I have "friends of coal" plates on my car, and my car truly is a friend of coal. It got me here on time today because it is powered with coal. It is an electric car, and it is charged by coal power. So I am very excited about coal as an abundant resource here in the United States because it gives us the opportunity to have energy independence and releases us from some of these foreign entanglements. So I am very troubled by what looks like the Administration's bias against coal, and I have been told by the engineers in my district, they just brought online in 2011 a super critical boiler unit. It is a state-of-the-art coal-fired facility at the Trimble County station, but they told me the other day that even though this thing qualified for clean energy tax credits and whatnot two years ago, today it would be illegal to build. They wouldn't be able to build it because it doesn't comply with the Administration's rules that are going to be promulgated.

Mr. Smith, could you tell me, is that correct? Would it be impossible to build a compliant coal station today without CCS technology?

Mr. SMITH. Well, thank you for the question, Congressman. I can't respond to the specific instance because I am not familiar with the plant or the details behind it, and——

Mr. MASSEY. Would it be possible to build a coal plant without CCS technology that is compliant today?

Mr. SMITH. Again, we are not the regulatory agency so, I mean, I really can't answer questions that are specific to how the regulations operate. I can talk to the technology pathways that we are pursuing, our broad Administration goals, how we are working with EPA. I could address those points.

Mr. MASSEY. Okay. Well, I will assume they were correct in stating that.

Let me ask you a question then that maybe you can answer. I think we need to—because we are determining policy, we can't base it on opinions. I am an engineer, and I believe that without facts, all you have is an opinion. So I am looking for facts and numbers here today. If the Earth has warmed because of human activity, can you tell me what percentage of that warming was due to anthropogenic causes?

Mr. SMITH. Mr. Congressman, what I can say, you know, without getting into a detailed scientific discussion——

Mr. MASSEY. I am just looking for a number like a percentage.

Mr. SMITH. What I can tell you is that we do believe the anthropogenic CO_2 production, anthropogenic greenhouse gas emissions are an important component of global warming and it is something that we do have to comprehensively address.

Mr. MASSEY. That is an opinion. So let us take it into the realm of facts. What percent would you apply to anthropogenic causes?

Mr. SMITH. Again, Mr. Congressman, I am not going to go through a peer review of scientific studies, and to select a number, I can't say that it is comprehensively important. We could certainly provide your office with more detail.

Mr. MASSEY. Well, I would love to see those facts, because every time somebody from the DOE comes here, we ask this question. We have never gotten an answer to that question.

I do have another question that is based on math, and this is a little bit easier exercise. What is the percent cost increase in coal production, coal-produced electricity that you associate with CCS technology?

Mr. SMITH. Well, right now we are looking at three, I guess, separate tranches in the way that we think about the implementation of CO_2 technology.

Mr. MASSEY. If it were ideally implemented, what would the additional costs be to a kilowatt-hour?

Mr. SMITH. Well, Mr. Congressman, it would depend on the state of the technology at the point of implementation.

Mr. MASSEY. I think in your testimony notes, you said between 35 and 70 percent. Is that a good range?

Mr. SMITH. I think that would be a reasonable range.

Mr. MASSEY. Okay. So let us say it is 50 percent, and if a middle-class family had a $200 electric bill in Kentucky, 50 percent of $200 is what?

Mr. SMITH. That would be $100.

Mr. MASSEY. Okay. So their electric bill would go from $200 to $300, and in 12 months they would have another $1,200 electric bill. Does the Administration—does the DOE care that this is going to push some people below the living standard and that more people may have to go on public assistance because of promulgating the carbon capture technology?

Mr. SMITH. The point that the—the position that the DOE takes on this is that these are technologies that are going to be critical to be developed. Our job is to make sure that they are done in a way that is most cost-effective, that minimizes the impact on consumers, that ensures that clean coal has a role in the clean energy economy of the future, ensures that we have energy security here in the United States, and that we have the maximum amount of energy diversity for families throughout the United States.

Mr. MASSEY. But you wouldn't dispute those numbers?

Mr. SMITH. I would say that if we do not move forward on these technologies, that we are not going to have a pathway to ensure that coal is part of the clean energy economy of the future. This is work that we must do to ensure that we do keep this important energy source.

Chairman LUMMIS. The gentleman's time is expired.

Mr. MASSEY. Thank you very much. I yield back.

Chairman LUMMIS. I am so sorry, Mr. Massie. The chair now recognizes the gentleman from California, Mr. Takano.

Mr. TAKANO. Thank you, Madam Chair.

Mr. Smith, I want to explore a little bit more about the competitiveness of coal vis-á-vis natural gas. Can you tell me the impact that the increased efficiency and the technology in terms of extracting natural gas have had on coal's competitiveness?

Mr. SMITH. Well, thanks for the question. It has had a pretty large impact. If we look at availability of natural gas and how it has changed over the past decade, you know, a couple data points. You know, I grew up in Fort Worth, Texas, as Mr. Veasey mentioned, the geographic mid center of the Barnett shale. When I grew up there, there was absolutely no gas production or very, very little, and now it has been an absolute boom. Prices for natural gas were, you know, creeping into the double digits at one point. They bottomed out at somewhere around $2 last year. And so as you have that large decrease in the price for natural gas, it makes—it brings another option for American consumers, and we think that is generally positive.

Mr. TAKANO. I mean, would it be fair to say that the viability of natural gas has become a war on coal?

Mr. SMITH. I would——

Mr. TAKANO. I am being a little facetious there. I am just saying that it seems like the market forces have more to do with coal's struggling than Administration policy.

Mr. SMITH. Markets have a lot to do with it, and it is also part of the rationale why we have to be working very closely with industry to make sure that we are working together to develop these technologies to make sure that coal remains relevant.

Mr. TAKANO. Well, let us talk a little more about coal versus natural gas. I mean, what makes natural gas such a more compelling source of energy on the fossil fuel side?

Mr. SMITH. Well, I would dispute the, I guess, categorization of more compelling because we think that energy diversity is very important and that in all-of-the-above, we have to make sure that we are using all of our energy sources. But I would say that natural gas has the benefit of having half of the CO_2 impact, and right now it is much more affordable than it was just five years ago.

Mr. TAKANO. Thank you for that. I mean, I don't mean to cast—so it just seems to me, just looking at the Administration's policies, that the expenditures that it is seeking to make to—it looks like it is trying to make coal competitive. I mean, I would characterize the Administration's policies as not a war on coal but an attempt to make coal competitive with other sources of energy so we have—because it is plentiful in our country. It is something in our back pocket that we can develop potentially in the future for energy independence.

Mr. SMITH. We believe that energy diversity is a very important part of the all-of-the-above strategy. Coal creates a lot of jobs, it creates a lot of economic benefits in those parts of the country in which coal production is important. We firmly believe that we are going—the clean energy economy of the future is going to be a carbon-constrained world, and the only way that we can ensure that there is a role for all of our energy sources, which is going to be good for our economy, good for our energy security, is to move forward with research and development to ensure that we are doing something about the problem that we have with coal, which is, it is a major emitter of CO_2. That is the challenge that we have to rise to, and that is the heart of our collaboration with industry, to move forward on these technologies.

Mr. TAKANO. So the way I—so I see—thank you for your comment. I think the policy of the Administration is really an attempt to be supportive of coal, to keep it as a viable source of energy in the future because it is so plentiful in our country. It will help us with energy independence, and it truly does contribute to the all-of-the-above strategy.

Mr. SMITH. I think that would be an accurate characterization of what our intent is.

Mr. TAKANO. Thank you.

Chairman LUMMIS. I thank the gentleman and yield four minutes to the gentleman from Texas, Mr. Weber.

Mr. WEBER. Thank you.

Chris, good to see you. I haven't seen you since you were down in Port Arthur at the opening of that plant. You said in your conversation with Congressman Neugebauer that you would categorically say it is not true that the Administration was waging a war on coal, but let me talk about that very fundamental question of the future of coal in America as it relates to President Obama's policies.

During his first campaign, the President famously said that his objective was to bankrupt anyone that tried to build a coal-fired power plant. Since that time, the President has worked hard to deny he was "waging a war" on coal. However, after the President announced he intends to aggressively pursue new climate regulations last month, in a moment of candor, one of his key advisors said, and I am quoting, "Politically, the White House is hesitant to say they are having a war on coal. On the other hand, a war on coal is exactly what is needed." Now, that was one of the President's advisors.

So my question to you, Chris, and I have got a list here for you, is what is the Administration doing? Is it much more important than what the President and advisors are saying? Do they say one thing and do another? And let me just say, consider this list of the recent pending regulations affecting coal. Number one: carbon regulations—I think my colleague down here, Mr. Massie, talked to you about it—on new coal power plants, carbon regulations on existing coal power plants, utility MACT with EPA estimated compliance costs of $10 billion, the Cross State Air Pollution Rule, which I know you are familiar with, BACT, or Best Available Control Technology, rules for greenhouse gas emissions, particulate matter regulations, section 316(b) rule concerning cooling water intake, and the list goes on and on and on. Effluent limitation regulations costing between $200 million and $900 million per year, new EPA regional haze requirements, new EPA monitoring—excuse me—mountaintop mining rules, Department of Interior stream buffer zone regulations, and forthcoming ozone regulations which are projected to be the most costly regulation in the history of the U.S. government, most recently estimated by not your agency but the EPA to cost $90 billion annually. And yet we say that the President's Administration, with all due respect to my colleague from California, says that the gas market has waged a war on coal. That is the free market and American entrepreneurs will take that free market and they will make that work. They will make that adjustment. Consumers will respond by buying those products. But it is a fact, in my opinion, that this Administration has a war on coal. In fact, there is a YouTube video out on him where he was campaigning and he said under his energy plan, electricity prices would of necessity skyrocket. And I am sorry, I am out of time.

You say that your mission is to make sure that America has clean, affordable energy. You say the future is a carbon-constrained world. But don't you think that given what I just said is happening, the only thing that is going to be constrained is America's economy and our world competitiveness?

Mr. SMITH. Well, thank you, Congressman. There is a lot there so I will try to comment, I guess, on the——

Mr. WEBER. You have got lots of time, 28 seconds.

Mr. SMITH. Okay. Great. Well, last month I saw you were down in Port Arthur in your district where we were doing a ribbon cutting for the Air Products project, which I think was mentioned by one of the panelists. I think that is the—I mean, we can talk about who said what in an unattributed article but if you look at what we have actually done, particularly here within the Department of Energy, particular our research and development projects, we are taking concrete actions to ensure that coal remains relevant. Market forces are going to do what they do. Certainly the emergence of natural gas has had a big impact on coal. The technological innovations around shale gas have pushed natural gas prices down. We think it is important that as we go forward that we are making the research, we are putting the research in place to ensure that coal does continue to have a role.

Chairman LUMMIS. Thank you very much. I am sorry. The gentleman's time has expired.

Mr. WEBER. I yield back.

Chairman LUMMIS. The chair now recognizes the gentleman from Texas, Mr. Hall, chairman emeritus of this Committee.

Mr. HALL. Thank you, Madam Chairman, and thank you yesterday for your good questioning and answering of the EPA people here. I think you put them in their place properly.

I want to just touch on the climate change research causation that was inquired. I think Mr. Smith quickly said yes when he thought that it was people that had caused it. Causation. I just—you know, we were told 12 years ago that it was going to be halfway or 12 feet up on the Statue of Liberty, and it is less than a foot up on the Statue of Liberty. All kinds of warnings and people coming before us being paid a lot to come here to testify that scared us to death. And just like going to the moon. We are going to go to the moon but we are not going to the moon until the people can go to the grocery store, and on global warming, we better well be aware that we are not getting any help from anybody hardly in the world on that. We are doing it ourselves, and for what little has been done, we don't know whether people caused it or not. We have spent $34 to $38 billion for the small steps that have been taken. I think before you answer yes to something like that, you ought to know the causation and what it has cost the taxpayers to get what little we have got there, and I hope the record will reflect that.

Ms. Greenwald, I know you, and I have served with you and admired you always. I can't remember if you were a Republican or a Democrat, though, when you were here.

Ms. GREENWALD. Do I have to say?

Mr. HALL. No, you don't have to. I just remember that we worked on the Clean Air Act Amendments and the Energy Policy Act, and since then we passed another landmark energy policy, 2005 Energy Policy Act, and you have seen the development of new technologies in your position. Rather than government mandates, what are the most effective methods of advancing energy technologies and efficiencies when we have a President Obama with his mandates, and he has not just got a war on coal, he has a war on energy. Could you give me some kind of an answer to that?

Ms. GREENWALD. Well, we believe that to get clean energy sources and energy efficiency into the marketplace requires a combination of policy and making sure that the market can work. So that is why we advocate for flexible policies and incentives so that you can set targets and requirements, but you leave to the private sector as much as possible the ability to make choices so that they pick the best technologies that can meet your environmental——

Mr. HALL. We need to be aware of it and abreast of it and never forget it and looking at it every day, but we need to be reasonable about what we have to spend with no help from people that ought to be assisting us. Have you answered my question? I think you have.

I will use the rest of my time. I have about 37 more seconds to go here. I am a coal—I am from Texas and I am a fossil fuels and oil and gas guy but I have seen coal operation make significant investments and progress in advancing clean air emission controls and employing advanced technology, so I am heavy on coal and I think that we really—this is an important meeting, and I thank all of you for your service. I yield back my five, four, three, two, one, time. Thank you, Madam Chairman. Thank you for your good work yesterday.

Chairman LUMMIS. Thank you very much.

We made it. The votes have been called on the Floor of the House, and everyone was very cooperative so everyone got to participate in this hearing today. We thank the witnesses so much for your valuable testimony and the Members for their questions. Members of the Committee may have additional questions for you, and we will ask you to respond to those in writing. The record will remain open for two weeks for additional comments and written questions from Members. We will look forward to your responses to those questions that you may be receiving shortly.

Before we adjourn, I ask unanimous consent to enter into the record two items. First, a letter signed by 23 Members of Congress, including me, to President Obama on July 22nd expressing our concern about the implementation of the New Source Performance Standards addressing greenhouse gas emissions for new and existing power plants. And secondly, two charts from DOE's International Energy Outlook, which was just released this morning showing the forecast for global coal demand, which is projected to increase by 39 percent in the next 20 years. Without objection, so ordered.

[The information appears in Appendix II]

Chairman LUMMIS. Obviously, those charts indicate that the subject of today's hearing is tremendously relevant, and the challenges exist for the technology that you espoused in your testimony, Mr. Collins. Ms. Greenwald. We look forward to your continued work, Mr. Yamagata, as well as the Department of Energy's continued work on fossil fuel technologies.

The witnesses are excused with our deep gratitude, and this hearing is adjourned.

[Whereupon, at 10:45 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Chris Smith

QUESTIONS FROM REPRESENTATIVE CYNTHIA LUMMIS

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Hearing on the Future of Coal: Utilizing America's Abundant Energy Resources
July 25, 2013

Q1. Please provide the current status of and outlook for the advanced fossil fuel conditional loan guarantees announced in 2009. Why have those conditional loan guarantees not yet been finalized?

A1. The Department has not issued any fossil energy conditional commitments to date.

Current applicants for fossil energy loan guarantees as of August 26, 2013 are as follows ($millions):

Program	Authority	Sector	Project Name	Requested Loan Amount
Fossil Projects - Due Diligence Pipeline				
Title 17	1703	Coal Gasification	Project 1	$ 2,815
Fossil Projects - On Hold				
Title 17	1703	Coal Gasification	Project 2	$ 1,750
Title 17	1703	Coal Gasification	Project 3	$ 1,700

Each of these projects has a number of open issues that need to be resolved before DOE could determine, as is required by statute, that there exists "a reasonable prospect of repayment of the principal and interest on the obligation by the borrower." Some of these issues involve local and state legislatures or other governing bodies, on which the Loan Programs cannot force a timeline.

QUESTIONS FROM REPRESENTATIVE CYNTHIA LUMMIS

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Hearing on the Future of Coal: Utilizing America's Abundant Energy Resources
July 25, 2013

Q2. In April, a report issued by the MIT Energy Review concluded that even with revenues from enhanced oil recovery (EOR), natural gas prices would have to be above $9 for a CCS plant to be economically preferable over natural gas. The Energy Information Administration is projecting that natural gas prices will remain below $6 for at least the next 20 years.

b. Please provide a detailed list of all non-CCS research activities, including award recipient, project description, date, funding amount, and length of activity.

A2b. All of the projects in the Fossil Energy (FE) clean coal program support FE's mission to enhance national energy security and to reduce emissions of greenhouse gases (GHG) from fossil fueled energy systems. **However, many of these projects also contribute toward the achievement of multiple other energy-related goals**. For example, advanced Integrated Gasification Combined Cycle (IGCC) plants reduce GHG emission due to their high efficiency and their ability to more easily separate CO2 from the process. However, depending on the process configuration, advanced IGCC plants can be used to produce electric power and/or chemical products. This concept, known as polygeneration, can be used to take advantage of changes in market demand and prices for products over time. Similarly, solid oxide fuel cells (SOFC) also offer high efficiency and an easily separated CO2 stream but in addition can operate at < 20% load (great for grid stability where large fluctuations in energy generation or demand exist) and provide a way to produce electric power, heat, and water from the same unit. In addition, innovative materials, sensors, and controls that are necessary for development and operation of these and other technologies e.g. advanced ultra-supercritical steam cycles, can be applied broadly to both the existing U.S. fleet of fossil fuel plants and to new plants resulting in improve efficiency, reliability, and lower cost operation.

QUESTIONS FROM REPRESENTATIVE CYNTHIA LUMMIS

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Hearing on the Future of Coal: Utilizing America's Abundant Energy Resources
July 25, 2013

Q3. DOE recently announced the availability of an $8 billion in authority for loan guarantees for advanced fossil energy projects. Are current activities funded through the Clean Coal Power Initiative or as part of the American Recovery and Reinvestment Act CCS demonstration projects eligible for these loan guarantees?

A3. The $8 billion in loan guarantee authority that has been allocated to fossil projects was made available under the Omnibus Appropriations Act of 2009. That Act prohibits the use of such authority, subject to certain limited exceptions, for loan guarantees for projects where "funds, personnel or property...of any Federal agency...are expected to be used...to support the project or to obtain goods or services from the project". Compliance with this limitation must be certified by the Director of the Office of Management and Budget. The determination whether this restriction would render a specific project ineligible for the 2009 loan guarantee authority is necessarily fact specific, and must be based on a thorough understanding of the project. It is not possible to say with certainty how a broad category of projects may be affected by the restriction.

QUESTIONS FROM REPRESENTATIVE CYNTHIA LUMMIS

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Hearing on the Future of Coal: Utilizing America's Abundant Energy Resources
July 25, 2013

Q4. The National Coal Council (NCC) is a Federal Advisory Committee tasked with advising the Secretary of Energy – at his request – on general policy matters relating to coal. The last five NCC reports focused exclusively on CCS and the NCC has not weighed in on non-CCS coal issues in over seven years. Given the critically important non-CCS technology and regulatory issues facing the coal industry, there are why hasn't DOE tasked the NCC to undertake a broader review of coal policy issues? Will DOE task NCC with such a request? If not, what is planned instead?

A4. For the past decade, the Department has focused on the issues associated with the largest market for the use of coal in the United States. That market by far is electrical power. Over the years, the NCC has produced excellent reports on a variety of topics including regulatory, policy, technology and market issues. The Department is presently in discussions with the NCC regarding the next study. There are a broad range of topics being considered including one related to coal policy issues.

QUESTIONS FROM REPRESENTATIVE CYNTHIA LUMMIS

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Hearing on the Future of Coal: Utilizing America's Abundant Energy Resources
July 25, 2013

Q5. **Please provide the current status of and outlook for the eight remaining CCS demonstration projects, including DOE obligated amounts, current phase, spending project to date, whether the project has received accelerated funding, and DOE/recipient cost share amounts and commitments by phase. Please also provide forthcoming key factors and decision points of the eight remaining CCS demonstration projects and how DOE will examine those points to determine each project's viability.**

A5. Listed below is the information requested on the eight remaining carbon capture and storage (CCS) demonstrations projects:

- Demonstration of a Coal-Based Transport Gasifier; Southern Company Services; Kemper County, Mississippi; ~$4.1B est. total plant cost, DOE share $270M ; Integrated Gasification Combined Cycle (IGCC); 3,000,000 tons of CO_2/year to EOR. Construction is continuing (~72% complete); shakedown of various unit operations has commenced with full integrated operations to begin in May 2014.
- Texas Clean Energy Project; Summit Texas Clean Energy LLC ; Penwell, Ector County, Texas; $3B total est. cost, DOE share $450M ; IGCC/polygeneration (baseloaded); 2,200,000 tonnes of CO2/year to EOR (Financial close expected in October 2013 with construction to begin shortly thereafter). Plant operation is scheduled to commence in late 2017.
- Hydrogen Energy California (HECA) Project; Hydrogen Energy California LLC (a project company owned by SCS Energy); Bakersfield, Kern County, California; $5B

total est. cost, DOE share \$408M; IGCC/polygeneration (load following); 2,570,000 tonnes of CO_2/year to EOR. Financial close expected in June 2014 with construction beginning in January 2015. Plant operation is scheduled to begin in mid-2019.

- W.A. Parish Post-Combustion CO_2 Capture & Sequestration Project; NRG Energy; Thompsons, Texas; \$775M total est. cost, DOE share \$167M; post-combustion capture at an existing coal-fired power plant; 1,400,000 tonnes of CO_2/year to EOR. Financial close is expected in March 2014. Operation is expected to begin in mid-2016
- FutureGen 2.0; FutureGen Alliance, Meredosia, Morgan County, Illinois; \$1.77B total est. cost, DOE share \$1.05B; oxy-combustion repowering; 1,000,000 tons of CO_2/year to saline storage. Financial close is expected in summer 2014 with construction beginning in the Fall 2014. Plant operation is expected to commence in mid-2017.
- Demonstration of CO_2 Capture and Sequestration of Steam Methane Reforming Process Gas Used for Large-Scale Hydrogen Production; Air Products & Chemicals; Port Arthur, Texas; \$431M total est. cost, DOE share \$284M. CO_2 from steam methane reforming for hydrogen manufacture at an oil refinery; 925,000 tonnes of CO_2/year to EOR. Plant operation began in December 2012 and reached full capacity in March 2013. As of August 14, 2013, over 420,000 short tons of CO_2 have been sold for EOR.
- CO_2 Capture from Biofuels Production and Storage into the Mt. Simon Sandstone; Archer Daniels Midland (ADM); Decatur, Illinois; \$208M total est. cost, DOE share \$141M (ARRA) (68%); CO_2 capture from an ethanol plant; 900,000 tonnes of CO_2/year to saline storage. Construction is continuing (~50% complete)' shakedown and commissioning of the CO_2 compression and dehydration facilities has been

initiated. Awaiting EPA Class VI injection well permit, expected January 2014, to begin drilling well. Plant operation expected to begin in July 2014, assuming EPA Class VI operating permit is issued in June 2014.

- Lake Charles Carbon Capture & Sequestration Project; Leucadia Energy LLC; Lake Charles, Louisiana; \$436M total est. cost, DOE share \$261M; CO_2 capture from a petroleum coke-to-methanol gasification facility; 4,500,000 tonnes of CO_2/year. Financial close is expected by December 2013 with construction to commence in January 2014. Plant operation is expected to begin in mid-2017.

QUESTIONS FROM REPRESENTATIVE CYNTHIA LUMMIS

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Hearing on the Future of Coal: Utilizing America's Abundant Energy Resources
July 25, 2013

Q6. The Department of Energy's flagship CCS demonstration project, FutureGen, has been fraught with cost overruns, project delays, and an ever-changing membership of the private consortium. Please provide an update on this project and the outlook for its successful completion.

A6. Former Secretary Steven Chu approved the continuation of the FutureGen 2.0 Program into Phase II in February 2013. This approval entailed the creation of several sub-phases designed to ensure the project meets important milestones on an aggressive schedule. At this time, the FutureGen project is on track to meet all of its Phase II milestones, and remaining funds are being expended in a timely manner. The FutureGen program has spent $92 million of the $1.048 billion obligated to the project, leveraging an industry investment of ~$717 million. Construction is currently scheduled to begin after financial close in Fall 2014 with operation commencing in Summer 2017.

QUESTIONS FROM REPRESENTATIVE KEVIN CRAMER

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Hearing on the Future of Coal: Utilizing America's Abundant Energy Resources
July 25, 2013

Q1. The Environmental Protection Agency is moving forward with greenhouse gas regulations on both new and existing coal-fired power plants. In EPA's initial regulatory proposal for new plants released last year, the EPA rulemaking assumed that CCS technology would be commercially available within ten years of a plant initiating operations.

a. Mr. Smith, do you agree that the proposed EPA rule – which I understand is now under revision – would effectively ban the construction of new coal plants without CCS?

A1a. On September 20, 2013, the EPA issued a new proposal for Carbon Pollution Standards for New Power Plants. The proposed limits for fossil fuel-fired utility boilers and IGCC units are based on the performance of a new efficient coal unit implementing partial carbon capture and storage (CCS).

QUESTIONS FROM REPRESENTATIVE KEVIN CRAMER

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Q1. The Environmental Protection Agency is moving forward with greenhouse gas regulations on both new and existing coal-fired power plants. In EPA's initial regulatory proposal for new plants released last year, the EPA rulemaking assumed that CCS technology would be commercially available within ten years of a plant initiating operations.

b. Would you also agree that in order for CCS to be part of a new coal plant, significant technical, legal, property rights, and liability issues must first be resolved?

A1b. In 2010, the Interagency Task Force on Carbon Capture and Storage issued a formal report regarding the status of carbon capture and storage (CCS) technology. The report found that "while there are no insurmountable technological, legal, institutional, regulatory or other barriers that prevent CCS from playing a role in reducing GHG emissions, early CCS projects face economic challenges related to climate policy uncertainty, first-of-a-kind technology risks, and the current high cost of CCS relative to other technologies." The report further found that the key barrier to CCS deployment is the lack of comprehensive climate change legislation.

A number of commercial-scale CCS demonstration plants supported by DOE will begin operation over the next five years, and these plants are expected to show considerable progress in addressing current challenges to CCS deployment.

QUESTIONS FROM REPRESENTATIVE KEVIN CRAMER

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Q1. The Environmental Protection Agency is moving forward with greenhouse gas regulations on both new and existing coal-fired power plants. In EPA's initial regulatory proposal for new plants released last year, the EPA rulemaking assumed that CCS technology would be commercially available within ten years of a plant initiating operations.

c. With that in mind, what is the earliest time frame in which you can state with confidence that CCS will be commercially available at utility scale?

A1c. Several commercial carbon capture and storage (CCS) technologies have already been developed in different industries and applications. Current carbon capture and storage (CCS) electricity generation and industrial demonstration projects are focusing on 1st generation technologies which are available today. These projects will begin operation over the next 5 years. These facilities are expected to show that CCS can be operated reliably, predictably, and safely at utility scale. The next generation of transformational CCS technologies will be even more economically attractive.

QUESTIONS FROM REPRESENTATIVE KEVIN CRAMER

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Q2. **Your testimony notes that commercial scale CCS will increase electricity prices between 35 and 70 percent. How is this pursuit consistent with your office's mission to ensure the nation can continue to rely on coal for affordable energy?**

a. **Please explain why DOE has decided to place nearly all of its resources into an unproven technology that, even if "successful," would increase electricity prices so dramatically, instead of a more balanced approach that could improve the efficiency and environmental performance of existing coal plants.**

A2a. The Office of Fossil Energy is charged with advancing technologies related to the reliable, efficient, affordable, and environmentally sound use of fossil fuels, which are essential to our Nation's security and economic prosperity. The focus of our research is reducing the overall cost of CCS by reducing CO_2 capture cost and other plant costs by improving plant efficiency and developing more cost-effective environmental controls.

With respect to the current cost of CCS systems, our studies show that CCS does add a cost relative to current wholesale electricity prices. Actual impacts on end users would depend on a range of factors including: ability to sell CO2 or other byproducts, local regulatory structure (e.g. some areas of the country currently have carbon prices) and whether the project receives other incentives (local and/or federal), as well as the level of capture implemented. In addition, in the absence of comprehensive climate change legislation the cost of energy related CO2 emissions is a negative externality borne upon the general public. FE RD&D is currently developing 2nd generation technologies that will improve the efficiency and reliability of carbon capture processes to facilitate the transition to a low-carbon energy system. Using recent EIA natural gas price forecasts, systems analyses indicate that a coal-fueled power plant with 2nd-generation CCS technologies could produce electricity at a cost that is competitive with a NGCC power plant without CCS. These technologies would be competitive when the CO_2 captured by the coal plant is sold for use in enhanced oil recovery (EOR). RD&D pathways are being explored that could further reduce CCS cost.

When evaluating the potential of advanced technology, it is important to consider both the potential future performance of a technology as well as future prices. A large portion of the Fossil Energy RD&D is focused on improving the efficiency and reducing the cost of the base power plant through gasification and other advanced power system improvements. In the past, FE has adjusted its R&D portfolio to be responsive to Administration and Congressional priorities, and will continue to do so if further diversification in its RD&D program is needed.

QUESTIONS FROM REPRESENTATIVE KEVIN CRAMER

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Q3. The Western Research Institute is developing WRITECoalTM gasification technology4 to greatly increase the efficiency of coal gasification. Will this technology be available for commercial application in the timeframes called for in the president's greenhouse gas regulations on new power plants?

A3. On September 20, 2013, the EPA issued a new proposal for Carbon Pollution Standards for New Power Plants. This technology could be available for commercial application in the timeframes called for in this proposal. The current R&D project ended in 2011 after successful bench and pilot scale testing of individual components of the technology.

[4] The WRITECoal Gasification technology is one that combines gasification with a coal upgrading process to significantly enhance efficiency and reduces capital cost. The technology is being developed by WRI with activities at a pilot scale today. The Lignite Research Council is contributing funds toward this technology along with the Department of Energy and the State of Wyoming.

QUESTIONS FROM REPRESENTATIVE KEVIN CRAMER

U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Q4. Are the resources available to affect technology development called for in the CURC road map developed with input from DOE, the Electric Power Research Institute, and the Coal Utilization Research Council membership?

a. Is the timeline outlined in the administration's proposed regulation consistent with the time required to allow for technology development and commercialization?

A4a. Today, the Department's Fossil Energy Clean Coal Program has the resources necessary to maintain a diversified advanced power systems and carbon capture and storage (CCS) research and development technology portfolio in order to achieve the cost, performance and environmental goals consistent with those outlined in the CURC road map. The new proposal for Carbon Pollution Standards for New Power Plants issued on September 20, 2013, is consistent with this research, which is focused on developing technology options that dramatically lower the cost of capturing carbon dioxide from fossil fueled energy plants.

Responses by Mr. Ben Yamagata

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Energy

Hearing Questions for the Record
The Honorable Cynthia Lummis

The Future of Coal: America's Abundant Energy Resources
Mr. Ben Yamagata

1. **There has been considerable speculation that the revision to EPA's 2012 proposed greenhouse gas regulations for new power plants will shift away from a presumption of CCS-driven compliance and instead focus on the simply mandating dramatic efficiency increases. How can DOE best contribute to the ability of coal powered facilities to meet the revised standards? Similarly, how can DOE contribute to industry efforts to comply with forthcoming regulations on existing plants so they will not be shut down?**

CURC would be supportive of any EPA regulations that implement new NSPS for greenhouse gases (GHG) for new coal-fueled power plants if such regulations were focused upon efficiency increases rather than CCS technology installations, which CURC has noted are not yet commercially available.

If provided sufficient time and adequate public financial support through public and private partnerships, we project that such CCS systems will be commercialized and cost competitive with other clean energy sources. For new units, improvements in overall power plant efficiency for combustion-based systems as well as significant cost reductions in gasifiers and improved gas turbines are projected to result in a levelized cost of electricity (LCOE) for these advanced coal fueled systems with CCS that is lower than today's coal-fueled power plants without CCS. CURC, in cooperation with EPRI (the Electric Power Research Institute), has developed a coal technology Roadmap that outlines these technology development needs and opportunities (please see: www.coal.org).

It is important that the DOE continue to develop these technologies and have sufficient funds to ensure a diverse portfolio of options are available to compete in a clean energy future, one which will include significant fossil fuel resources.

The Administration's FY 2014 recommended funding level of $276.6 million is not sufficient to accomplish the important R&D necessary to support the technology development that is needed. Neither is the amount of appropriations provided by the House of Representatives in its FY 2014 Energy and Water Appropriations bill for the Department of Energy's coal R&D program. Reduced federal funds will reduce private and public investments, slow development timelines, and could cause the abandonment of promising new technologies at a time when we should be aggressively supporting the development of technologies designed to overcome environmental concerns of coal use. The CURC-EPRI Roadmap recommends $372 million per year in funding for DOE's coal R&D program for fiscal years 2014 through FY 2018.

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Finally, the CURC is currently investigating possible R&D collaborative efforts with industry directed at our nation's fleet of existing coal fired units. Issues related to unit reliability, flexibility, efficiency and modeling of water use for a variety of coal technologies as well as to develop technologies to reduce water withdrawal and consumption at power generation facilities. Importantly, these potential areas of cooperative R&D are intended to best ensure the continued operation of our low cost, highly reliable existing coal fleet.

2. **What are the potential economic and energy security consequences of recent and forthcoming EPA regulations on existing coal-fired power plants? How might DOE's $370 million coal R&D portfolio be better prioritized to help coal utilities comply with tightened regulations while improving environmental performance?**

Other organizations, including the Energy Information Administration (EIA), have concluded that a variety of market related circumstances (i.e. the cost and availability of natural gas, and environmental regulations; e.g. the regulation of hazardous air pollutants, particularly mercury) will likely cause the retirements of a significant number of existing coal units -- at least 50GWs of coal-fired capacity out of a total of 310 GWs have already been announced for retirement. EPA has been directed by the President to issue proposed section 111(d) Clean Air Act regulations by June of 2014 to regulate carbon dioxide (CO2) emissions from existing coal-fired units. These proposed regulations could have a significant impact upon existing units, as well. EIA, for example, projects that coal-based generation will decline by 60 – 94% between 2012 and 2040 if CO2 regulations result in a "cost" of $15 to $25/tonne of CO2. With current carbon, capture and sequestration (CCS) technologies costing 3-4 times these amounts, it is only through a robust and focused coal R&D program that we can bring down costs. And, in addition to CCS technology development, we believe that DOE's coal R&D program should be more balanced to address other critical technology areas important to continued coal use in the US. For example, the program does not focus upon those technology needs applicable to the existing fleet of coal power plants – that will in turn assist in complying with forthcoming EPA regulations – by addressing improved efficiency, reliability, water management, and flexibility in generation.

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3. **The CURC-EPRI Coal Technology Roadmap identifies a number of research areas not currently being addressed by DOE that may warrant additional investment. Among those, what one or two areas should be the highest priority?**

CURC fully supports the Department's development of cost-effective technology to capture and use or store CO_2. However, there are several other areas of critical technology development that require attention and support.

For example, the CURC-EPRI Roadmap recommends establishment of a water management program. In addition, CURC has long called for a well-funded program to develop advanced materials to support the increased temperatures and pressures of advanced coal using systems. Much progress has been made with industry and next steps include the development and funding of a pilot facility to ensure that these advanced material efforts are expeditiously furthered.

Additionally, as noted in the CURC/EPRI Roadmap, the DOE program also should support "breakthroughs" in technology R&D across several program areas that encourage revolutionary approaches to converting coal to useful energy and products. Importantly, the emphasis of this initiative is a focus on new ways to use coal. An example of a breakthrough technology might include the substitution of biosystems for current chemical processes.

4. **Coal generates approximately 40% of global electricity and developing nations continue to build coal-fired power plants at a rapid rate. Even if the United States does not construct any new coal-fired power plants, there will be an extensive worldwide market for the material and system components for new units. Please describe the global market implications for fostering domestic expertise in associated coal technology systems.**

As we consider questions about climate change and U.S. regulatory programs, we believe it is worth noting that if the United States simply were to abandon coal, a scenario that is unrealistic, the impact to global CO_2 emissions would be relatively small. To combat global CO_2 emissions, the U.S. must play a lead role in the development of technologies that can (and will) be deployed in China and India and elsewhere, to reduce global carbon

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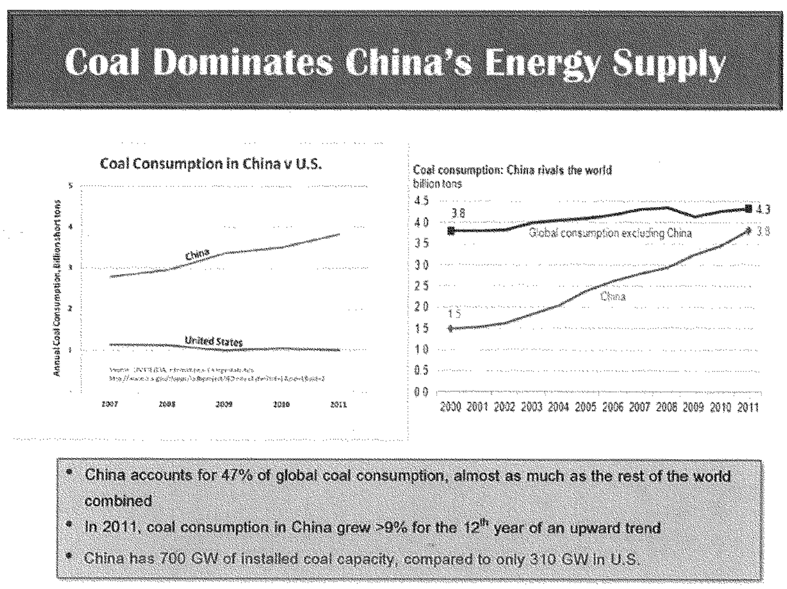
emissions. Without technology innovation in this country, and initiatives sponsored and supported by the Department of Energy (DOE), a significant reduction in global GHG emissions is unlikely (see chart below).



We do not believe, given the current lack of any consensus among nations to address CO2 globally, that CCS technology development will occur without strong U.S. leadership. It is generally recognized, also, that coal use worldwide will grow enormously as noted in the charts above. Thus, if CO2 abatement is to be addressed and coal use continues at such a dramatic rate, then CCS technologies must be developed. U.S. technology leadership, under these circumstances is vital and taking this leadership position will ultimately place

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Mr. Ben Yamagata

U.S. industry in the forefront with the technologies and know-how to address CO_2 emissions.

Responses by Mr. Don Collins

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TESTIMONY

Follow up Question Responses

Donald W. Collins, Jr.

Chief Executive Officer

Western Research Institute

Laramie, Wyoming

Submitted to the

Honorable Cynthia Lummis

Chairman

Before the

Subcommittee on Energy

Committee on Science, Space and Technology

U.S. House of Representatives

Hearing on The Future of Coal:
Utilizing America's Abundant Energy Resources

July 25, 2013

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1. Low rank coal resources are defined in part because of the high water content embedded in the resources. With the ongoing drought in the west and southwest, is there sufficient water contained in this coal that might help alleviate the strains on the water system?

We believe the answer is yes as every contribution will be important to help alleviate strains on water systems in drought regions of the U.S. The lack of water in drought risk areas of the west and southwest is a high priority of the power industry from the perspective of continued operation with the existing fleet, as well as future steam-based power plants (e.g., nuclear, natural gas combined cycle, concentrated solar, biomass and coal). It is essential to explore every opportunity to lessen the distress in this important region of the U.S. Low-rank coals provide one such opportunity as water is delivered with low-rank coals, and the U.S. is rich in low-rank coal resources. In the past this natural source of water has gone untapped. New technology allows utilization of water delivered with low-rank coals such that local water consumption for plant feedwater could be significantly reduced.

Currently, subcritical plants typically receive water from surface structures (e.g., rivers) and/or from groundwater. All steam-based and water cooled power plants thereby compete for water with household, agricultural, recreational and other commercial usages. Power plants use water in three specific areas (1) boiler feedwater, (2) wet scrubber or spray dryer absorber for SO_2 emissions; and (3) condenser cooling in cooling towers. Each of these areas requires make-up water of different quality and level of treatment. Figure 1-1 provides the water quality and cost for pulverized coal (PC) and circulating fluidized bed (CFB) plants. Water recovery benefits projected with retrofit of WRITECoal technology highlights the benefit for boiler feedwater – the highest quality and highest cost water use within PC and CFB plants. The largest consumption of water is for cooling tower make-up water. The net consumption of water with recycle is approximately 25% based on a 4:1 cooling tower cycle concentration discharge, which is typically used to condition the ash co-product.

Sources of Water Make-up for PC & CFB Power Plants

	Water Quality	WRITECoal™ Recovery use
Boiler Feed-water	High Quality & Cost	Yes 100%
SO_2 Scrubbers	Low Quality & Cost	Yes (18-25%) No Upgrading
Cooling Towers	Medium Quality & Cost	Yes No Upgrading

Note CFB's use dry in-bed sorbent for SO_2 capture, thereby no water use or loss.

Figure 1-1. Comparison of Conventional Coal Plant Water Use Areas and WRITECoal™ Clean Coal Technology Process

The WRITECoal™ process uses plant waste heat in large part to (1) reduce water consumption for plant use, (2) remove approximately 75%, or more, of the mercury from low-rank coal, (3) increase efficiency, and (4) lower the cost of electricity by utilizing low-rank coals. The WRITECoal™ process provides clean water that can be used in any of the three plant areas with in some cases with minimal water treatment. For a 550 MWe subcritical plant the amount of water recovered by the WRITECoal™ process from a 28% moisture Powder River Basin coal is 213 gpm, while the water recovered from a 38% moisture North Dakota lignite is 316 gpm. This amount is enough water to meet 100% of the boiler feedwater makeup which is the most expensive and has the highest quality water standard requirements. Optionally, the water from low rank coals extracted by the WRITECoal™ process can be used to supply 18% to 28% of the makeup water for the lower quality scrubber/SDA or the cooling water.

National Energy Technology Laboratory (NETL) analysis results shown in Table 1-1 depict the water demand, the internal recycle (process discharge), and the raw water withdrawal for an existing 550 MWe subcritical plant without CO_2 capture has a water demand of 6,553 gpm and a raw water net consumption of 5,270 gpm. With Econamine CO_2 capture (emissions of 1,100 lbs CO_2/MWh), the water demand is 8,048 gpm and raw water consumption of 6,352 gpm and with 90% CO_2 capture (emissions of 334 lb/MWh), the water demand is 8,948 gpm, and water net consumption of 6,869 gpm. This increase in water demand and net consumption with increase CO_2 capture is the result of an increase in cooling load and the significant use of low pressure (LP) steam by the Econamine process.

Table 1-1. Make-up Water by Use Category with Different Levels of CO_2 Capture[1]

	No CO_2 capture	62% (1,100 lbs/MWh)	90% (334 lb/MWh)
BFW Make-up	78	78	79
FGD Make-up	846	858	852
Cooling Tower Make-up	5,629	7,089	7,985
Total	6,553	8,048	8,948

Table 1-2 shows the water demand for wet cooling condensers and hybrid cooling (50% wet and 50% air). For the non-capture supercritical (SC) PC and ultra-supercritical (USC) PC, the water demand was reduced by 1,760 and 1,700 gpm/MWnet respectively for the hybrid cooling system compared to a wet cooling system yielding a 46% reduction in water usage. The non-capture CFB hybrid reduces the water demand by 1,730 gpm/MWnet compared to an all wet system for a 49% reduction.

For 90% CO_2 capture, the SC and USC PC the reductions are 1,270 gpm/MWnet and 1,130 gpm/MWnet respectively for about an 18% reduction. For the 90% CO_2 capture CFB plant the reduction in water demand is 19% (1,250 gpm/MWnet).

[1] The water demand/consumption shown in Table 1-1 is from DOE/NETL-401/110509 report dated November 2009 and is based on a wet cooling tower.

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Table 1-2. Impact of Cooling Tower Type on Water Demand (gpm/MWnet) and Relative Costs.

	Subcritical PC		SC PC		Relative
	No Cap	90% Cap	No Cap	90% Cap	Cost
Wet Cooling	3826	6684	3696	5947	1X
Hybrid* Cooling	1760	1270	1700	1130	2X
Air Cooling	0	0	0	0	3-4X

Note. CO_2 capture by Econamine

Figure 1-2 shows the water demand and water consumption for a range of new or new coal-fired power plants. (DOE/NETL-2011/1463). Figure 1-2 includes the CFB SC case mentioned earlier.

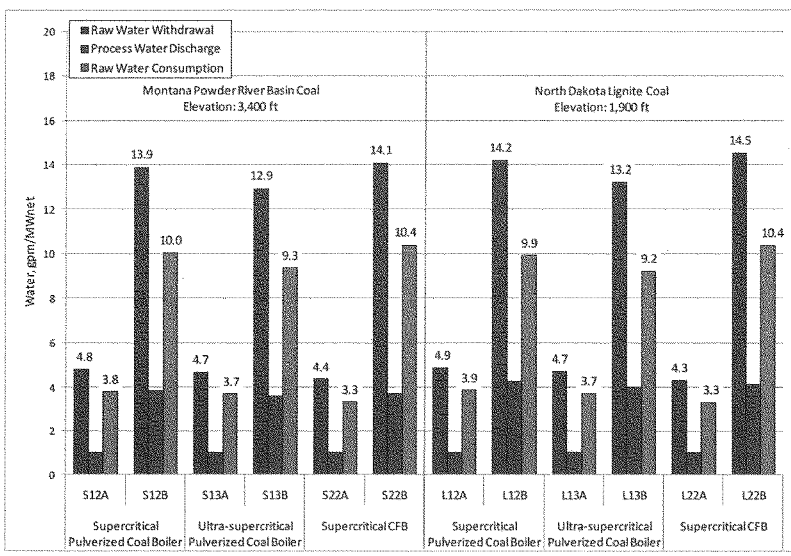

Figure 1-2. Summary of the Water Demand/Consumption for Various Coal-fired Plant Scenarios.

A number of efforts are being investigated to lower the water demand and water net consumption requirements for retrofitting existing plants and for new plants. These include:

(1) Use lower quality water resources instead of water sources that compete with agriculture (e.g., municipal water reclamation discharge water to lower raw water withdrawal by up to 50%;

(2) Air-cooled condensers or hybrid air/wet cooled condensers (cooling circuits). As shown in the Table 1-2 and Figure 1-2 show the major reduction in water demand due to deployment of air and hybrid cooling system compared to conventional water ('wet') cooling systems. Unfortunately, the cost of a hybrid system is twice that of a wet system and the air cooling system is 3-4 times that of a conventional wet cooling system, dependent on the temperature and humidity conditions of the yearly plant seasonal cycle. Deployment progress and hence societal benefits are not forthcoming as the industry has substantial financial disincentives to implement beneficial low-water cooling systems due to New Source Review requirements that would impose additional investment expenses that exceed viable cash flow and investment recovery business conditions.

New coal-fired subcritical, SC PC or CFB plants with carbon capture (via Econamine) increases the water demand on a per MWe basis due to the increase in parasitic power. The amine process uses steam for the carbon capture, thereby increasing water demand. The CFB plants use in-bed sorbent SO_2 capture thereby eliminating the water requirements for the scrubbers or SDA.

WRI's concept of new oxy-combustion plants (PC or CFB) with natural gas combined cycle plant to supply the parasitic power can lower the water demand compared to PC plants alone with amine-based CO_2 capture. Additional research and development to further reduce water net consumption in coal, natural gas combined cycle, biomass, concentrated solar, and nuclear based power plants is needed for the longer-term economic sustainability and environmental health of the region and our country.

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2. **Much of the debate regarding the use of coal in our energy portfolio includes the release of heavy metal emissions. Your testimony suggests that mercury emissions from China's use of coal which are transported in the atmosphere and deposited in the United States. Could your coal drying technology offer an avenue to reduce such emissions cost-effectively?**

The quick answer is, "Yes." Lowering mercury levels within low-rank coal prior to utilization in generating electric power, provides opportunities to save on capital costs to install mercury capture on all power plants and also saves recurring costs for operation, maintenance and safe disposal of captured mercury for each power plant. If substantial quantities of mercury are removed from the coal at the mine site, then it can be safely returned to whence it came when mine site reclamation occurs. This also lowers transportation costs of captured mercury since the drying plant is located adjacent to the mine.

Regarding mercury deposition in the western U.S., Chinese, and Asian, mercury emission sources are well documented in modeling and ground-based sampling. In an updated study on global mercury emissions to the atmosphere, N. Pirrone et al reported, "On an annual basis, natural sources account for 5207 Mg of mercury released to the global atmosphere, including the contribution from re-emission processes, which are emissions of previously deposited mercury originating from anthropogenic and natural sources, and primary emissions from natural sources." Regarding anthropogenic mercury emissions N. Pirrone et al reported, "Anthropogenic sources, which include large number of industrial point sources, are estimated to account for 2320 Mg of mercury emitted annually. The major contributors are from fossil-fuel fired power plants (810 $Mgyr^{-1}$), artisanal small scale gold mining (400 $Mgyr^{-1}$), non-ferrous metals manufacturing (310 $Mgyr^{-1}$), cement production (236 $Mgyr^{-1}$), waste disposal (187 $Mgyr^{-1}$), and caustic soda production (163 $Mgyr^{-1}$). Therefore, our current estimate of global mercury emissions suggests that the overall contribution from natural sources (primary emissions + re-emissions) and anthropogenic sources is nearly 7257 Mg per year[2]..."

The authors provide updated data to breakdown the mercury emissions which reveals that nearly 400 $Mgyr^{-1}$ of the 810 $Mgyr^{-1}$ annual global mercury emissions from stationary combustion is attributed to China (268 Mgyr-1) and India (124.6 $Mgyr^{-1}$) with North American accounting for 65.2 $Mgyr^{-1}$ of the 810.

According to the National Atmospheric Deposition Program, "Atmospheric lifetimes of elemental mercury are estimated to be up to two years, and as methyl mercury in the soils for decades." This allows non-U.S. mercury emissions to intermix in the atmosphere with significant amounts later depositing within the U.S. Figures 2-1 and 2-2 illustrate the change in measured mercury concentration from 2003 to 2011[3] within the U.S. A recent study by the Electric Power Research Institute (EPRI) assessed the annual mercury deposition within the U.S. by foreign sources. Figures 2-3 and 2-4 provide the results of this EPRI study and 2002 assessment to highlight the significance of increasing mercury deposition in the U.S. from foreign sources. Therefore, we see noteworthy environmental and health benefits for our country by exporting a low-mercury content coal to Asian countries.

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[2] Although not broken out by the authors, it is recognized that re-emissions accounted for under natural mercury sources should attribute a portion of re-emissions to mercury that originated from anthropogenic sources.
[3] It is noted that some of the difference between 2003 and 2011 is related to the better monitoring measurement capabilities that have been deployed since 2003.

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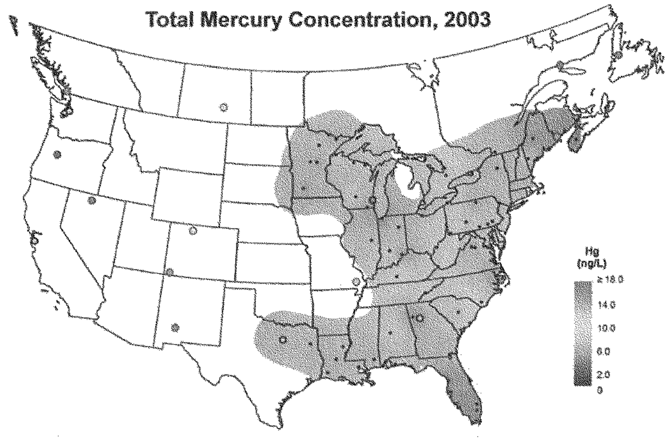
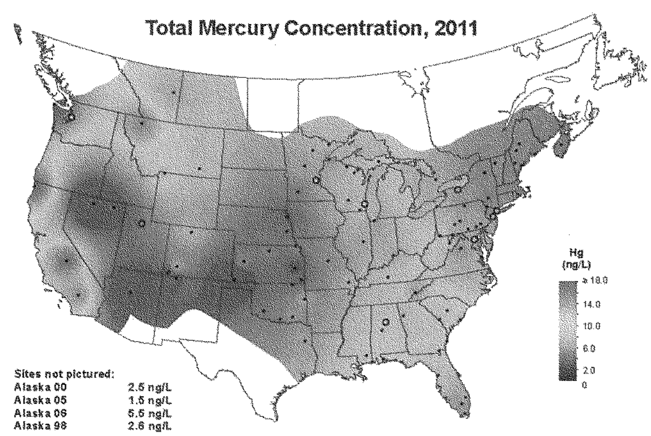


National Atmospheric Deposition Program/Mercury Deposition Network
http://nadp.isws.illinois.edu

Figure 2-1. U.S. Mercury Concentration Map for 2003



National Atmospheric Deposition Program/Mercury Deposition Network
http://nadp.isws.illinois.edu

Figure 2-2. U.S. Mercury Concentration Map for 2011

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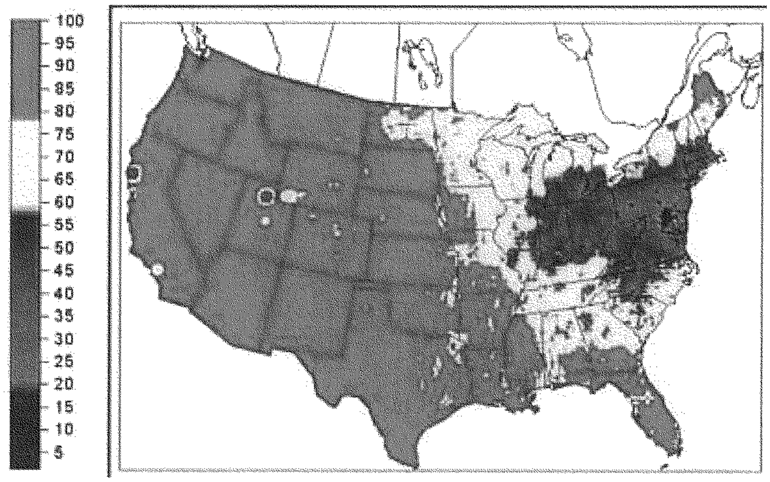

Figure 2-3. Mercury Emitted in China attributed Mercury Deposition in the U.S.

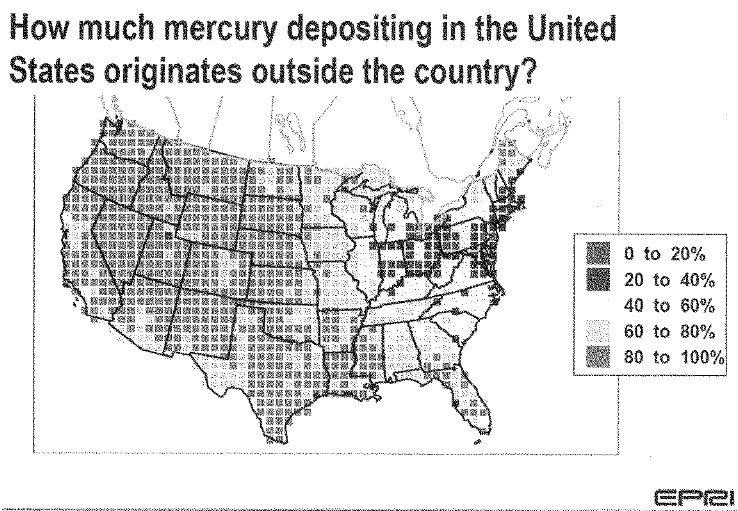

Figure 2-4. EPRI Foreign Sources of Mercury Deposition in the U.S. circa 2002[4]

[4] Source: Monroe and Levin, "Mercury Control a Utility Perspective", 2003 Advanced Combustion Engineering Research Center Conference

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In essence there are two ways in which technology being developed by Western Research Institute that can assist in this issue. The first is the development of the WRITECoal™ process which we described in our written testimony. The WRITECoal™ process uses plant waste heat in large part to reduce water for plant use, remove approximately 75% of the mercury (Hg) from Powder River Basin coal, increase efficiency and lower the cost of electricity generated using U.S. low-rank coals. The WRITECoal™ process can perform equally well for the low-rank, high moisture coals in China. The process also reduces arsenic (As) emissions by up to 60% and selenium (Se) emissions by 20-40% from the utilization of low-rank coal for power generation.

The WRITECoal™ process is a power plant technology that reduces moisture to essentially zero (<1%) and provides substantial capture of trace metals (e.g., Hg, As, Se) prior to the coal entering the boiler and is implemented at the utility just prior to pulverization and injection into the combustor. The water delivered with the low-rank coal is also captured for later use to replenish the plant boiler feedwater. The moisture reduction and the metals are done in separate steps that allow for the production of clean water and the separation of metals in a dry atmosphere allowing high capture performance by sorbents. As such, WRI is working with groups in China as well as extensively in the U.S. to deploy the technology. Analysis of the costs have shown that as little as $10 increase of the price of delivered coal to the utility will increase the cost of electricity produced by 0.7 to 1.0 cents increase in electricity – a significant increase of 10-15% to rate payers in Wyoming and the U.S.

Another technology option to assist in reducing mercury emissions from utilization of coal in China and the resulting mercury deposition within the western U.S. is to partially dry low-rank coals and remove a large percentage of the mercury at the mine-site prior to exporting coal to China and other Asian countries. Western Research Institute is advancing one such technology with our industry partner, River Basin Energy (RBE). This mine-site technology was first developed to produce a higher energy coal for export. By adding metal capture technologies to the coal drying process, a substantial amount of the naturally occurring metals can be captured and safely returned to the mine during the site reclamation work to create wildlife habitat areas.

In this RBE process, the coal reabsorbs 6-8% moisture that helps reduce the tendency for spontaneous combustion allowing transport to the power plant. The costs of this process would increase the price by $9-11/ton of coal processed (FMI). The coal in the case of China would be shipped to ports in the northwest by rail trans-loaded and shipped overseas to China, trans-loaded to rail and shipped to their power plants. This coal in this scenario would be used for power instead of local Chinese coal resources. However, the costs of the rail to Northwest port, trans-loading to ship, ocean transport, trans-loading of the coal at entry into China, and rail to the power plant could be considerable, perhaps in the range of $30/ton above the raw coal price at the mine. In addition, the concept of exporting Wyoming coal to China though ports in the northwest has been met with resistance by environmental groups and the States of Washington, Oregon and California. Although we have not performed an extensive cost analysis, this rather large cost increment could be unacceptable for China power.

The export of PRB coal to China would most likely be used for higher valued applications, such as coal-to-liquids instead of power generation where the better quality, lower ash and reactive, PRB coals could be preferred over local coals for certain conversion processes and could entertain the higher coal prices.

Both of these scenarios should be of high priority and it is worthwhile to define the economics of these different approaches to the issue of mercury emission from Chinese sites that are atmospherically transported eastwardly and end up being deposited in the western U.S.

3. Your testimony discussed the need to develop integrated energy systems to live in a "carbon rich" world. Please elaborate on this point and explain how this approach can be integrated into the policy-making decision process.

Thank you for the opportunity to discuss further my thoughts concerning human contribution to global warming/climate change discussions, and policy solution approaches and possibilities. For more than several hundred million years, the circulation of carbon has been a key planetary aspect of our ecosystem. Integrating natural carbon circulation systems with increased anthropogenic activities is a multifaceted systems integration problem with many complexities and opportunities to affect sustainable energy and societal system solutions.

It is only relatively recent in terms of the planetary time scale following the Industrial Revolution that humans have understood and contemplated environmental stewardship and sustainable energy matters as knowledge of harmful natural resources and ramifications of anthropogenic activities has come forth; thanks in large part by the available of low cost electricity provided by coal. Coal-based electricity has supported numerous technological achievements and advanced medical treatments that have substantially extended human life expectancy.

The context for living in a "carbon rich" world is a growing global economy, an increasing population of middle class consumers, and a longer living population around the world. The context of the global economy provides system-wide sustainability challenges and hence opportunities to improve. It is reasonable to think that global population growth and the associated food consumption will increase anthropogenic contributions to global warming/climate change as human longevity and population growth increasingly change the historical natural planetary systems, including thermal energy and greenhouse gas equilibrium. Such change is an on-going reality unless humankind ceases development and population growth and/or devises sustainable solutions to recycle and reuse all resources. It is also reasonable to consider that pursuing policies to constrain life expectancy, food consumption, and quality of life to enable lowering global CO_2 emissions is not a tenable option.

Developing integrated energy systems within a sustainable global economy entails applying systems engineering methods that begin with setting the stage for stimulating numerous solution ideas by exploring and clarifying all aspects of the problem to then architect high-level system solution performance objectives. A key outcome is establishment of solution performance goals rather than defining specific ways to achieve the performance goals. The latter approach applied to policies constrains innovation and typical yields less effective solutions while inefficiently deploying financial and natural resources, and human talent.

Consideration of the various elements included in discussions on the contribution of humans in global warming/climate change necessitates considering that population growth itself is a key contributing factor to future heat (thermal energy) and CO_2 emissions. As a carbon-based life form, we convert food into chemical and thermal energy and CO_2 and other emissions. The food system within our global economy entails processes to produce, process, and transport food to population centers, and then to dispose of waste materials. To feed the world population, the food system consumes energy and adds

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thermal energy and CO_2 into the atmosphere. Integrated energy system sustainable solutions should address the nexuses between energy, water and food, in addition to environmental concerns.

Conversation over the past few decades has evolved much conventional thinking aimed at pursuing a carbon-free or post-carbon world which in the extreme is not viable given that humans are in fact carbon-based life forms. This brings to light the need to explore thoughts and ideas outside of the conventional understanding and beliefs of what is needed and what is possible. A key to successful research and viable technologies is unconventional thought[5]. This includes the capacity for the research community to allow unconventional thought within itself and for society to allow thinking outside the blogosphere beliefs that constrain innovation pursuits. Highly effective systems integration and in turn policy is inhibited by such constraining beliefs and therefore requires proactive management of beliefs.

For example, there is reason to be concerned that use of survey polls that tally beliefs of groups of people and scientists to guide policy development undermines the integrity of the Scientific Method. The Scientific Method is a process through which a hypothesis or set of hypotheses are envisioned to in turn guide research activities aimed to bring forth knowledge to enable answering the questions that could not previously be answered. The integrity of this method is essential to determine whether or not a hypothesis was correct and can withstand the test of time such that quality policy options can be identified and implemented. Though scientists may believe that a hypothesis is likely to be proven true, there is great risk in making important policy decisions based upon a belief in an unproven hypothesis that entails significant known shortcomings rather than a proven and independently validated hypothesis. This is especially more vital when the belief is used to prescribe what solutions should be pursued and thereby constrain pursuit of alternative innovative solutions that could be more beneficial.

Pursuit of living in a "carbon constrained" world policy substantially constrains creative thought and innovative technological solutions that could achieve better sustainable energy and economic balance as the global economy continues to grow and increases consumption of energy as well as all natural resources.

If policies allow thinking and research on how best to live in the "carbon rich" world in which we live, then we can dramatically open the research community to pursue innovative ideas to achieve sustainable utilization of all forms of energy resources, recycle of energy, and use for energy conversion discharge compounds, including CO_2. A reasonable question to explore is, "Is it possible to recycle energy by thinking unconventionally and considering CO_2 as resource rather than a compound to be avoided?"

During the hearing, I found Congressman Massie's discussion about driving an electric car with batteries charged with electric from coal very interesting in that it provides an integrated systems solution nexus

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[5] In his book "How to Think Like Einstein" author Scott Thorpe highlights the ability and need to think past conventional accepted beliefs to avoid constraining innovative thought progress and solution advancements such as Einstein did when he developed his revolution game changing concepts. The key point is to proactively understand when efforts are guided and constrained by beliefs and then to ask, "What if things were different than a belief suggests?"

between the power and transportation sectors to achieve a net reduction in anthropogenic heat and CO_2 emissions. In his story lies an integrated energy system policy opportunity to enhance the sustainability contributions of coal. Combined with utilization of coal power plant CO_2 emissions by chemoautotrophic bacteria discussed in my written testimony to produce synthetic diesel for the transportation sector coal-based electricity to charge electric car batteries provides a means to achieve greater national CO_2 emission reduction and increased energy security and sustainability.

Integrated energy system concepts should include other industry sectors to enable more efficient societal systems that produce and use energy and the co-products to form beneficial nexuses with other industry sectors and societal systems. Today this is not done well in our societal structures and rules. For example, the energy sector decoupling regulation of the past several decades while enabling certain innovations also hinders achieving benefits of integrated systems. In parts of the U.S., energy resource extraction, power generation and delivery elements within the energy sector are not allowed to communicate nor strategically plan and invest to improve system-wide efficiencies and realize associated environmental and economic benefits. The capacity to integrate across the entire energy sector is increasingly critical as environmental issues are addressed and global competition for energy resources is projected to accelerate.

As emerging and developing country economies grow from subsistence living to middle class life style consumption, we can anticipate increasing supply competition and shortages unless we devise effective recycle and reuse solutions for all resources, including energy. From an integrated systems thinking approach, it is vitally important to allow unconventional thinking and conversation to pursue solutions that can better serve our nation and planet compared to policy objectives that focus primarily on constraining CO_2 emissions. In addition, to scientific research and technology applied RD&D, we will need to work on regulation changes to enable integration opportunities across historically disconnected industry and societal sectors so that we can maximize societal efficiencies.

Appendix II

Additional Material for the Record

SUBMITTED LETTER FOR THE RECORD BY
SUBCOMMITTEE ON ENERGY CHAIRMAN CYNTHIA LUMMIS

Congress of the United States
Washington, DC 20515

July 22, 2013

The Honorable Barack Obama
The President
The White House
1600 Pennsylvania Avenue, N.W.
Washington, D.C. 20500

Dear Mr. President:

We are writing to express our grave concern about your intentions to implement New Source Performance Standards (NSPS) addressing greenhouse gas emissions for new and existing power plants as outlined in your June 25, 2013 speech at Georgetown University. Circumventing the will of Congress, which has repeatedly voted against carbon regulations, taxes, and cap and trade, this speech directs EPA to take the unprecedented step of imposing an energy tax by regulatory fiat. This catch-all proposal would unfairly penalize existing facilities and almost certainly preclude the construction of new coal-fired plants.

We and others have often criticized a "War on Coal" waged by this White House and these accusations were met with firm denial by Administration officials and environmentalist allies. However, given the cumulative impact of continued mining permit delays, EPA regulations, and your annual budgets' repeated proposed cuts to the Department of Energy's fossil energy research and development programs, it is hard to come to any conclusion other than that your Administration is systematically trying to eliminate the use of carbon fuels, particularly coal. More to the point, Mr. Daniel P. Schrag of the President's Council of Advisers on Science and Technology finally feels comfortable admitting: "Politically, the White House is hesitant to say they're having a war on coal. On the other hand, *a war on coal is exactly what's needed*." This remark by a senior White House "expert" demonstrates that these policies are explicitly an attempt to drive coal from the marketplace.

Even before the announcement of the NSPS greenhouse gas rules, the harm inflicted by recent regulatory attacks on jobs and coal were clear. Rules such as Mercury and Air Toxics Standards have raised the cost of doing business in the electric utility industry by billions of dollars annually and mandated pollution control technologies that either do not exist or are commercially unviable. At a time of sustained high unemployment and a weak economic recovery, particularly in Appalachia and the former manufacturing hubs of the Rust Belt currently burdened with double-digit jobless rates, piling on billions of dollars in additional red tape further undermines our economy and weakens the long-term outlook for these communities. For example, between 2011 and 2012, Kentucky lost 5,700 coal jobs, 4,100 of which last year alone – a decline of 29.9%. According to your Administration's own figures, the number of coal mining jobs dropped by 3,300 in West Virginia in 2012. Statistics like these are repeated throughout our nation's coal-producing states. As dire as these numbers are, they cannot truly reflect the hardship confronting the proud, hardworking men and women who have been forced into the unemployment lines.

Sadly, Appalachia is not alone. Fully one-fifth of the nation's coal plants – 204 plants across 25 states – closed between 2009 and 2012. Seven EPA regulations proposed over the last four years will cost $16.7 billion annually once fully implemented. Power plants of any type are multiyear, multibillion dollar projects, and this onslaught of regulations will deter the investment in new facilities as older plants are retired and a recovering economy renews energy demand. The rate hikes attendant with the loss of 69,000 megawatts of coal-fired power are forecasted to cost 887,000 mining, utility, shipping, and downstream manufacturing across the country per year. The manufacturing sector, which was making a comeback due largely to affordable energy, will again be put at a cost disadvantage compared to foreign competitors.

Ultimately, these policies pose a challenge not only to our economy, but also to our national security. The United States has 250 years worth of domestic coal reserves at current consumption rates. These resources, combined with oil, natural gas, nuclear, and renewables could finally make the United States energy secure – a goal of every presidential Administration since Richard Nixon.

We ask that you stand with our constituents, our coal miners, and our coal communities by rejecting these proposed NSPS greenhouse gas regulations to reflect the true commercial realities of different fuel types and control technologies. Staying the present course will only prove disastrous: increasing unemployment, raising costs for American families and businesses, and reducing our energy security.

Sincerely,

Harold Rogers
Member of Congress

Shelley Moore Capito
Member of Congress

Nick J. Rahall, II
Member of Congress

Robert Aderholt
Member of Congress

Mike Simpson
Member of Congress

Bill Shuster
Member of Congress

Jo Bonner
Member of Congress

John Carter
Member of Congress

Robert E. Latta
Member of Congress

Brett Guthrie
Member of Congress

Gregg Harper
Member of Congress

Cynthia Lummis
Member of Congress

Phil Roe
Member of Congress

Lou Barletta
Member of Congress

Bill Johnson
Member of Congress

Mike Kelly
Member of Congress

David McKinley
Member of Congress

Todd Rokita
Member of Congress

Steve Stivers
Member of Congress

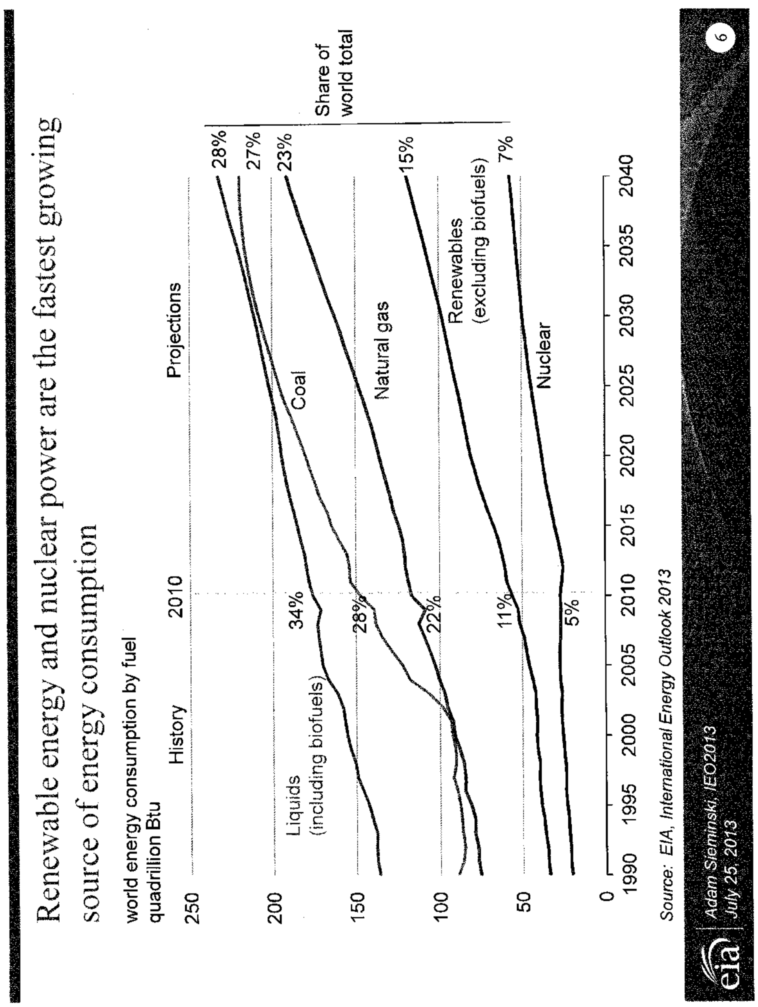
Thomas Massie
Member of Congress

Andy Barr
Member of Congress

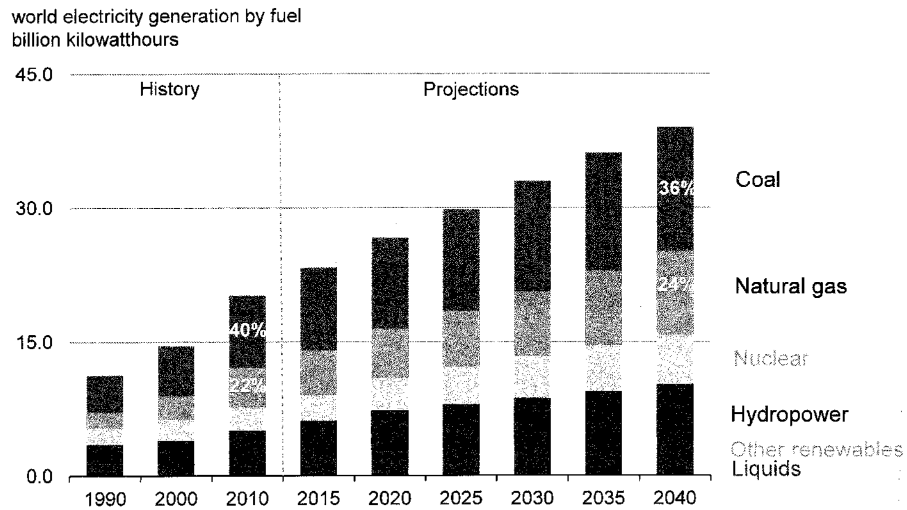
Steve Daines
Member of Congress

Keith Rothfus
Member of Congress

DEPARTMENT OF ENERGY'S INTERNATIONAL ENERGY OUTLOOK CHARTS SUBMITTED FOR THE RECORD BY CHAIRMAN CYNTHIA LUMMIS



In electricity generation, renewables and natural gas are the fastest growing sources, but coal still fuels the largest share in 2040



Source: EIA, International Energy Outlook 2013