Testimony of Shannon Angielski

Executive Director

Carbon Utilization Research Council (CURC)

Before the

Committee on Science, Space, and Technology

Subcommittee on Energy

Hearing on "Fossil Energy Research: Enabling Our Clean Energy Future"

CURC Testimony:

"Advancing Fossil Energy Technology Innovation in the U.S."

Washington, D.C.

June 19, 2019

## EXECUTIVE SUMMARY OF CURC TESTIMONY: KEY POINTS

CURC is an industry coalition focused on technology solutions for the responsible use of our fossil energy resources in a balanced, low carbon generation portfolio. CURC's members include many of the largest coal producers in the nation, electric utilities and power generators that rely upon coal and natural gas for electricity production, equipment manufacturers and technology innovators, national associations that represent the power generating industry, national labor unions, and state, university and technology research organizations. Members of CURC believe that American fossil fuels and ingenuity in technology innovation will satisfy the our world's growing appetite for affordable energy, improve our energy security, increase exports of U.S. resources and manufactured energy equipment, create high-paying jobs, and improve environmental quality. In order to meet these important objectives, members of CURC are at the forefront of their organizations and partnering with the Department of Energy to develop and commercialize technologies that will transform the way we use fossil fuels. Successfully achieving these objectives will require a strong public-private partnership with the federal government providing strategic investments in research, development and demonstration (RD&D).

Consumption of fossil fuels is on the rise both domestically and internationally, and this trend is projected to continue well into the future due to the role fossil fuels play in providing easily accessible, reliable and low-cost energy. According to the International Energy Agency and United Nations Intergovernmental Panel on Climate Change, carbon capture, utilization and storage ("CCUS") is a critical component of the portfolio of energy technologies needed to reduce carbon dioxide emissions worldwide. The U.S. has been a leader in the development of this technology with the support of the Department of Energy's ("DOE") world class carbon capture and storage programs. Through a federal grant, DOE supported the nation's first commercial-scale carbon capture demonstration project that is successfully operating on a coal-fired power plant in the U.S. – the Petra Nova project in Texas. As the U.S. continues to invest in CCUS, we will benefit not only from cleaner power, but also from new markets for U.S. technologies both domestically and abroad. Investment in carbon capture, utilization, and storage technologies will transform carbon dioxide into an economic resource, lower the cost of reducing emissions, create jobs, save consumers money, and safeguard our environment.

Congress made a critical step last year in catalyzing a CCUS industry in the U.S. through the enactment of the FUTURE Act to extend and expand the Section 45Q carbon sequestration tax credits. These credits are already incentivizing CCUS project across several industries. However, today's CCUS technology is still at the earliest stages of deployment and thus relatively expensive to implement in some industries like the power sector, and improved carbon capture technologies will be needed to reduce costs. Like the wind and solar industries that were just emerging 15 years ago, a combination of federal incentives such as tax credits and federal funding for research, development and demonstration will be needed to improve the technology so costs can be reduced. That is why the draft bill that is the subject of today's hearing is very important for an emerging CCUS industry, as it would authorize a new federal program for the U.S. Department of Energy to partner with the private sector in support of the research, development and demonstration activities necessary to accelerate commercial applications of carbon capture, storage, utilization and transformational, advanced power cycles. Such a program is necessary to compliment other federal and state policies that will enable a CCUS industry.

CURC members and the Electric Power Research Institute (EPRI) are constantly evaluating technology development needs that reflect the changing markets and policies that impact fossil fuel use. Every 2 to 3 years, those technology assessments are communicated through the publication of an Advanced Technology Roadmap. Last summer, CURC and EPRI published the *2018 Advanced Fossil Energy Technology Roadmap* which identifies pathways to accelerate the development of transformational coal and natural gas generating options that include carbon capture. The window for achieving transformational improvements in dispatchable generation is closing.

Over the next decade, over half of our existing coal and nuclear units will be candidates for retirement. According to EIA data, the average age of coal and nuclear fleet will be, on average, 60 years old in 2030. For power companies, the time to 2030 is a short time for new generation planning, which typically spans a period of 15 years. New, low emission baseload and dispatchable options that are cost competitive in the electricity market with other forms of low carbon technologies will be required to replace even just a portion of the dispatchable capacity necessary to maintain a diverse portfolio of electricity generation sources in the fleet of the future.

The good news is that there are several transformational technologies identified in the *Roadmap* that can serve as candidate, low carbon replacement options and still provide the dispatchable power needed to support the growth of renewables on the grid. These include novel fossil power cycles or key processes in such cycles that are designed to facilitate the capture of $CO_2$ at a lower energy penalty and cost than conventional methods. These processes are inherently more efficient, resulting in fewer emissions of both $CO_2$ and criteria pollutants, and require fewer fossil fuels to be used to produce electricity. There is specific research identified in the Roadmap that is also necessary to support these new cycles, including advancements in turbine technologies, and high-temperature materials necessary to achieve higher efficiencies. In addition, the *Roadmap* outlines advances in carbon capture technologies designed to lower costs, and the development and testing of these technologies at test centers such as the Wyoming Integrated Test Center and the National Carbon Capture Center in Alabama. Research on breakthrough technologies is also needed to ensure “out-of-the-box” thinking or fundamentally new approaches to solving fossil fuel’s challenges are developed.

Many of the technologies identified in the Roadmap are readying for pilot testing now and a few are preparing for commercial-scale demonstration. It is critical that federal policies support not only the R&D outlined in the *Roadmap*, but also the piloting and demonstrating of these innovative, first of a kind technologies. This means annual federal budgets should increase in the next several years to support the scale-up effort.

It is also important to note that Congress ensured that new technologies that receive funding through the federal RD&D program and are demonstrated at facilities such as PetraNova are not considered as a basis for regulating a federally mandated emissions standard. CURC very much supports the intent of Congress through the proviso included in the Energy Policy Act of 2005, which was enacted to alleviate private sector risk with implementation of new, early stage technologies that are not yet economic or commercial. CURC urges Congress to maintain this proviso by adding it to the Fossil Energy Research and Development Act of 2019.

Analysis conducted by CURC and ClearPath, with modeling provided by NERA Economic Consulting and Advanced Resources International, shows that there are significant economic benefits to the U.S. if the technology development outlined in the Roadmap is undertaken under a wide range of scenarios. Our analysis projects up to 87 GW of market-driven carbon capture deployment paired with enhanced oil recovery by 2040, resulting in a significant increase in domestic oil production and lower cost retail electricity rates, all of which contribute to substantial increases in annual GDP as well as over 800,000 new jobs through 2040. These macroeconomic benefits are described in more detail in my written testimony.

CURC is pleased to testify before the House Science, Space and Technology Committee in support of the draft bill, the “Fossil Energy Research and Development Act of 2019”, as it embodies the technology recommendations of the *2018 Roadmap*. We look forward to working with the Members of this Committee as you advance the legislation and to incorporate additional language that will address the effect of implementation of new technologies funded through this program for purposes of setting emission standards.

Thank you for the opportunity to provide this testimony.

## INTRODUCTION AND BACKGROUND

CURC is an industry coalition focused on technology solutions for the responsible use of our fossil energy resources in a balanced, low carbon generation portfolio. CURC's members include many of the largest coal producers in the nation, electric utilities and power generators that rely upon coal and natural gas for electricity production, equipment manufacturers and technology innovators, national associations that represent the power generating industry, and state, university and technology research organizations. Members of CURC believe that American fossil fuels and ingenuity in technology innovation will satisfy the our world's growing appetite for affordable energy, improve our energy security, increase exports of U.S. resources and manufactured energy equipment, create high-paying jobs, and improve environmental quality. In order to meet these important objectives, members of CURC are at the forefront of their organizations and partnering with the Department of Energy to develop and commercialize technologies that will transform the way we use fossil fuels. Successfully achieving these objectives will require a strong public-private partnership with the federal government providing strategic investments in research, development and demonstration (RD&D).

We are pleased to testify before the House Science, Space & Technology Committee in support of a draft bill, the "Fossil Energy Research and Development Act of 2019", which would authorize a new federal program through the U.S. Department of Energy to partner with the private sector in support of the needed research, development and demonstration activities to accelerate commercial applications of carbon capture, storage, utilization and transformational, advanced power cycles that support the goals of the legislation.

The U.S. has made significant strides in the development of advanced coal and natural gas technologies to improve the utilization of these resources. Similar to how a new car today can travel further on a single gallon of gasoline than one built in the 1980s, the most advanced coal units operating in the U.S. today can produce 20% more electricity than the previous generation of coal units with the same amount of fuel. With further technology improvements, additional efficiency gains of similar magnitudes can be achieved for both coal and natural gas combined cycle systems. New technologies have also resulted in significant emissions reductions since the early 1970s, even while coal use substantially increased. Additionally, technology has substantially reduced the use and discharge of water from fossil fueled power plants, and is the reason why we have fracking technology that has allowed our nation to unlock the potential from our vast natural gas resources.

Technology for the use of our nation's coal and fossil fuels is important, as these resources are growing in the global and domestic energy economy. Domestically, coal and natural gas comprised 80% of total U.S. energy consumption[1] and 63.5% of net electricity generation[2] in 2018. The U.S. Energy Information Administration (EIA) estimates that coal and natural gas will provide 58% of total U.S. net electricity generation in 2040[3] (see Figures 1 and 2). Globally, consumption of coal and natural gas are projected to provide 45% of our energy consumption in 2030 and will grow to nearly 50% of global consumption by 2040 (see Figure 1).

[1] EIA Today in Energy, April 16, 2019. https://www.eia.gov/todayinenergy/detail.php?id=39092
[2] EIA FAQ, Updated March 1, 2019. https://www.eia.gov/tools/faqs/faq.php?id=427&t=3
[3] EIA 2019 Annual Energy Outlook. https://www.eia.gov/outlooks/aeo/pdf/appa.pdf

**Figure 1 - U.S. and World Energy Consumption[4]**

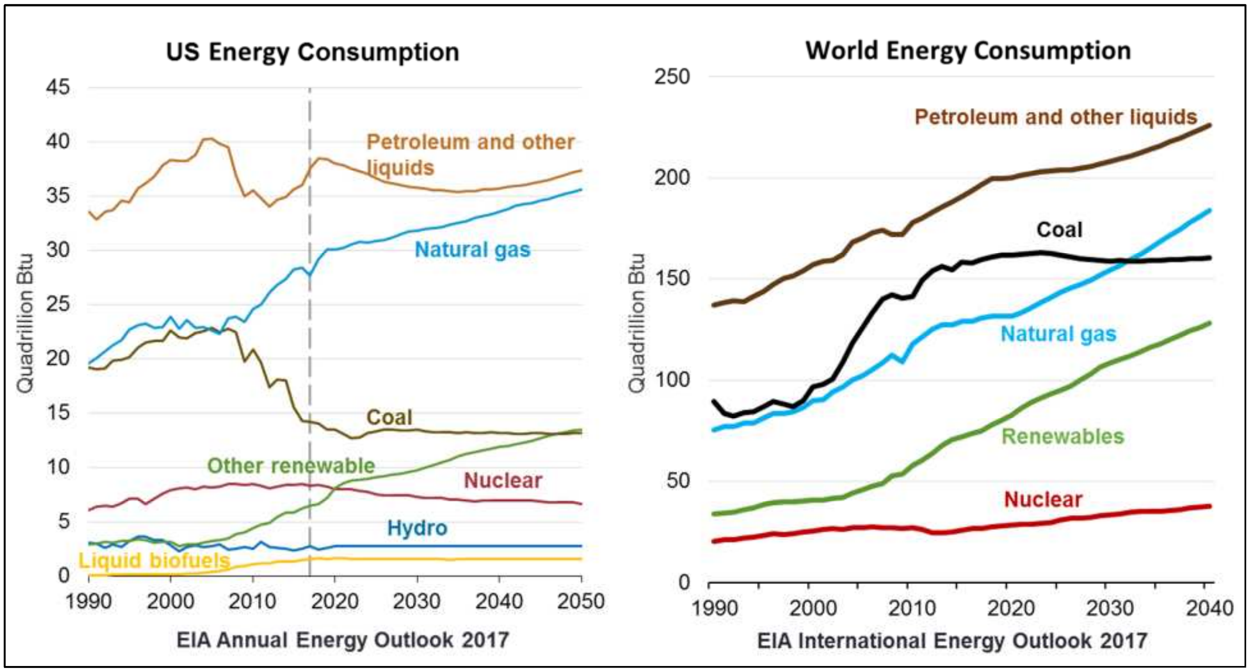
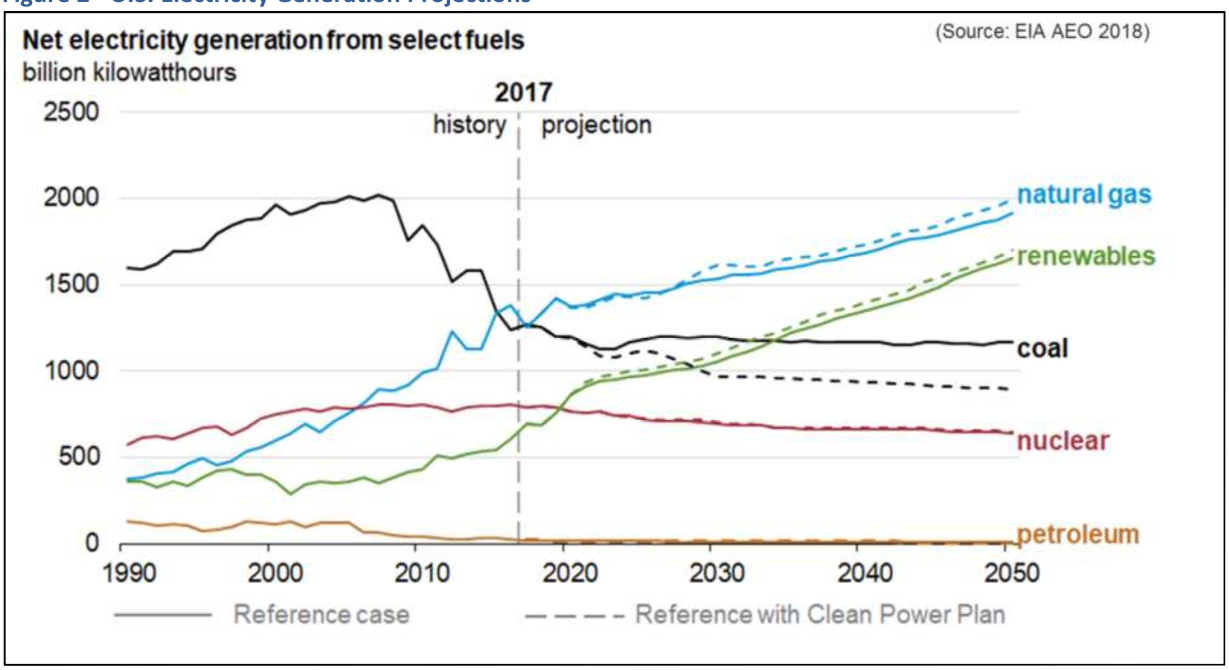


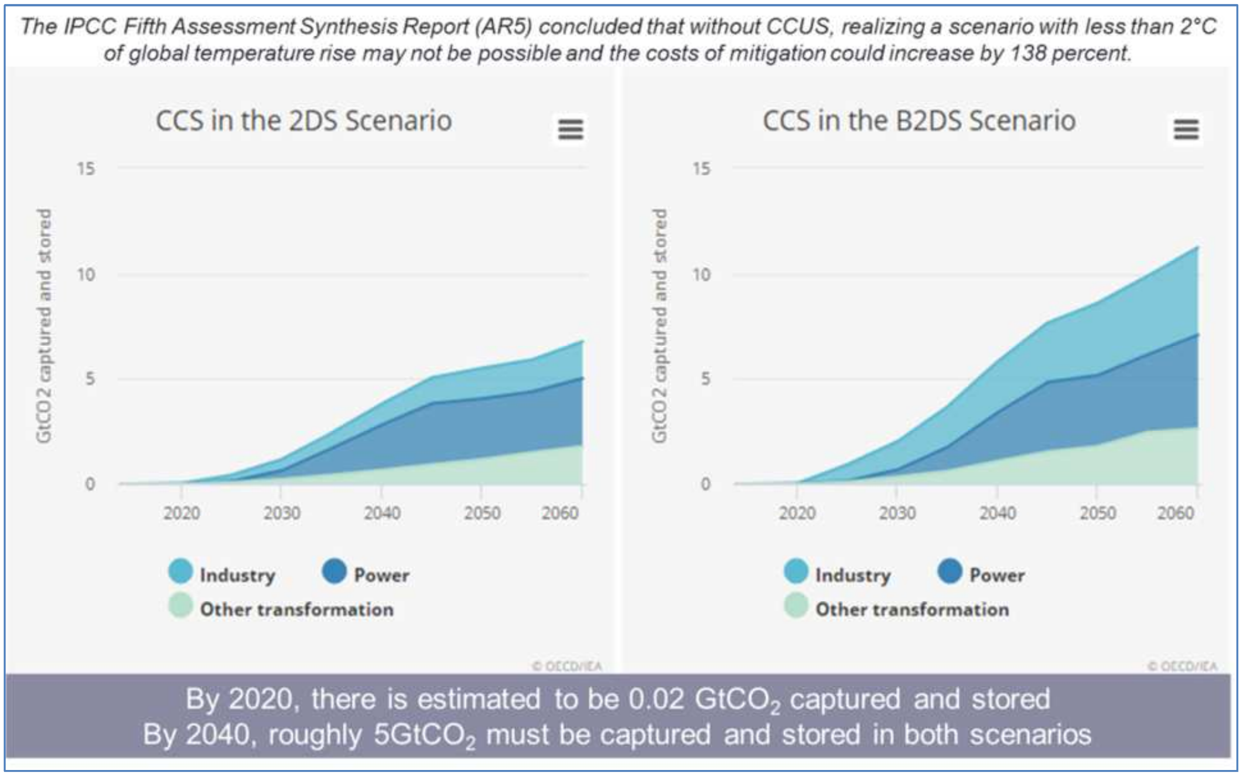

**Figure 2 - U.S. Electricity Generation Projections[5]**




Technologies to address the growing use of fossil fuels in the power sector must be developed and deployed to reduce the carbon footprint from the growing use of fossil fuels. Several international models show the need for CCUS technology that significantly reduce carbon dioxide ($CO_2$) emissions to meet global climate targets (see Figure 3).

[4] EIA Annual Energy Outlook 2017, EIA International Energy Outlook 2017.
[5] U.S. EIA Annual Energy Outlook 2018.

**Figure 3 - Importance of Technology in Meeting Global Climate Targets**[6]




The U.S. has been a leader in the development of CCUS technology with the support of the Department of Energy's ("DOE") world class carbon capture and storage programs. Through a federal grant, DOE supported the nation's first commercial-scale carbon capture demonstration project that is successfully operating on a coal-fired power plant in the U.S. – the Petra Nova project in Texas. As the U.S. continues to invest in CCUS, we will benefit not only from cleaner power, but also from new markets for U.S. technologies abroad. Investment in carbon capture and utilization technologies will transform carbon dioxide into an economic resource, lower the cost of reducing emissions, create jobs, save consumers money, and safeguard our environment.

Congress made a critical step last year in catalyzing a CCUS industry in the U.S. through the enactment of the FUTURE Act to extend and expand the Section 45Q carbon sequestration tax credits. These credits are already incentivizing CCUS project across several industries. However, today's CCUS technology is still relatively expensive to implement in some industries like the power sector, and improved carbon capture technologies will be needed to reduce costs and transform the way we convert our fossil fuels to electricity in order to be cost-competitive with other low carbon generating options. Like the wind and solar industries that were just emerging 15 years ago, a combination of federal incentives such as tax credits and federal funding for research, development and demonstration, will be needed to improve the technology so that it can be cost-competitive with other forms of low $CO_2$ emitting technologies.

That is why the draft bill that is the subject of today's hearing is very important for an emerging CCUS industry, as it would authorize a new federal program for the U.S. Department of Energy to partner with the private sector in support of the research, development and demonstration activities necessary to accelerate commercial applications of carbon capture, storage, utilization and transformational, advanced power cycles. Such a program is necessary to compliment other federal and state policies that will enable a CCUS industry.

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[6] U.S. International Energy Agency, Carbon Capture and Storage, http://www.iea.org/topics/carbon-capture-and-storage/

It is also important to note that Congress ensured that new technologies that receive funding through the federal RD&D program and are demonstrated at facilities such as PetraNova are not considered as a basis for regulating a federally mandated emissions standard. CURC very much supports the intent of Congress through the proviso included in the Energy Policy Act of 2005, which was enacted to alleviate private sector risk with implementation of new, early stage technologies that are not yet economic or commercial. CURC urges Congress to maintain this proviso by adding it to the Fossil Energy Research and Development Act of 2019.

CURC members and the Electric Power Research Institute (EPRI) are constantly evaluating technology development needs that reflect the changing markets and policies that impact fossil fuel use. Every 2 to 3 years, those technology assessments are communicated through the publication of an Advanced Technology Roadmap. As an independent, nonprofit organization for public interest energy and environmental research, EPRI focuses on electricity generation, delivery and use in collaboration with the electricity sector, its stakeholders and others to enhance the quality of life by making electric power safe, reliable, affordable and environmentally responsible. EPRI does not advocate or aim to influence policy or regulation.

Last summer, CURC and EPRI published the *2018 Advanced Fossil Energy Technology Roadmap* which identifies pathways to accelerate the development of advanced coal and natural gas generating options, as the window for achieving transformational improvements in dispatchable generation is closing. Over the next decade, a significant amount of coal and nuclear generation will be candidates for retirement. According to EIA data, the average age of coal and nuclear fleet will be, on average, 60 years of age in 2030. For power companies, this is a short time period for new generation planning, which typically spans a period of 10 to 15 years. That timeframe assumes existing units will not retire early due to economics or other market conditions that have led to recent premature retirements of coal and nuclear facilities. New, low emission technologies that are cost competitive in the electricity market will be required to supply the replacement baseload capacity necessary to maintain a diverse portfolio of electricity generation sources in the fleet of the future

This is the fifth Roadmap that CURC and EPRI have published since 2003. The 2018 Roadmap is a departure from prior Roadmaps published by CURC and EPRI as it includes new data on recent advances in technology for not just coal, but also natural gas in electric power generation. It also reflects the technology development needs that can support an evolving U.S. power sector impacted by several emerging trends driving innovation and investment decisions for new generation. Some of these trends include increased and low-cost domestic supplies of natural gas, slow, and in some areas of the country, declining, load growth and electricity demand, and the need for generation to rapidly adjust to cycling load demands with increased intermittent renewables on the grid.

The *Roadmap* outlines several RD&D pathways for both new and existing coal and natural gas technologies that will result in a suite of low-carbon, fossil-fuel platforms capable of being cost competitive with other forms of electricity generation in future electricity markets.

## SUMMARY OF CURC-EPRI ROADMAP FINDINGS

The technology pathways outlined in the *2018 Roadmap* will deliver cost-competitive and low or near-zero $CO_2$ emissions generation technologies that also mitigate the environmental footprint of using fossil fuels through reduced water consumption and other air emissions. Our analysis determined that many technologies are applicable to both coal- and natural gas-fired power generation, through which public-private sector funding and support can be leveraged to develop technologies for applications using both resources.

Several technologies identified in the *2018 Roadmap* will generate a new learning curve and result in new approaches for power generation and/or carbon capture to enable substantial breakthrough performance improvements and cost reductions. These encompass a broad range of technology improvements, including thermodynamic improvements in energy conversion and heat transfer, turbines and $CO_2$ capture systems that all drive cost reductions as well as reduce the consumption of energy needed to operate the $CO_2$ capture system. These technologies will result in a step change improvement in performance, efficiency, flexibility, environmental performance and cost from the use of fossil fuels (see Table 1 in Appendix). For each of these technologies, the *2018 Roadmap* identifies the cost and performance targets and the technology development necessary to bring each technology to commercialization will hitting those targets. The development needs and funding requirements for each technology are rolled up into an overall technology development timeline and funding schedule. The *2018 Roadmap* identifies a level of RD&D to ensure timely solutions are developed and pursued through aggressive public-private partnerships.

Example transformational technologies identified in the *Roadmap* include pressurized oxy-combustion, chemical looping combustion, and supercritical carbon dioxide ($sCO_2$) cycles, which would replace steam with $sCO_2$ as the working fluid – including both the direct- and indirect-fired $sCO_2$ cycles. New turbines and other components to support the higher temperatures and pressures of these systems, particularly the $sCO_2$ cycles, are also considered. Each of these new technologies is projected to be extremely efficient, be more compact and lower cost, and are designed to yield lower costs and energy penalties associated with the capture of $CO_2$.

The *Roadmap* also evaluates the cross-cutting development needs for a range of technologies applicable to both coal- and natural gas-firing units. Cross-cutting technology priorities identified in the *Roadmap* include development of high-efficiency materials development, carbon capture, carbon utilization, carbon storage, turbines, water management technologies, and sensors and controls to improve diagnostic and predictive capabilities.

Materials development can be leveraged across a suite of technologies.  Advanced Ultra-supercritical (A-USC) materials enable Rankine cycles with steam temperatures of 700°C or higher and are also needed for high-temperature and pressure power cycles. The Roadmap identifies the RD&D needs for A-USC materials development, the testing of A-USC materials and components under real operating conditions and demonstrating supply-chain fabrication capability for key full-scale A-USC components.

The *Roadmap* also considers carbon capture development paths for solvents, sorbents and membranes for post-combustion capture, and chemical and physical absorbents and membranes for pre-combustion capture systems, which are projected to have much lower energy penalties, yielding higher efficiencies and lower costs. Carbon capture technologies in the *Roadmap* address pathways for both coal-fired power plants and NGCC plants. CURC recommends that any federal program for carbon capture supports both coal and natural gas technology pathways.

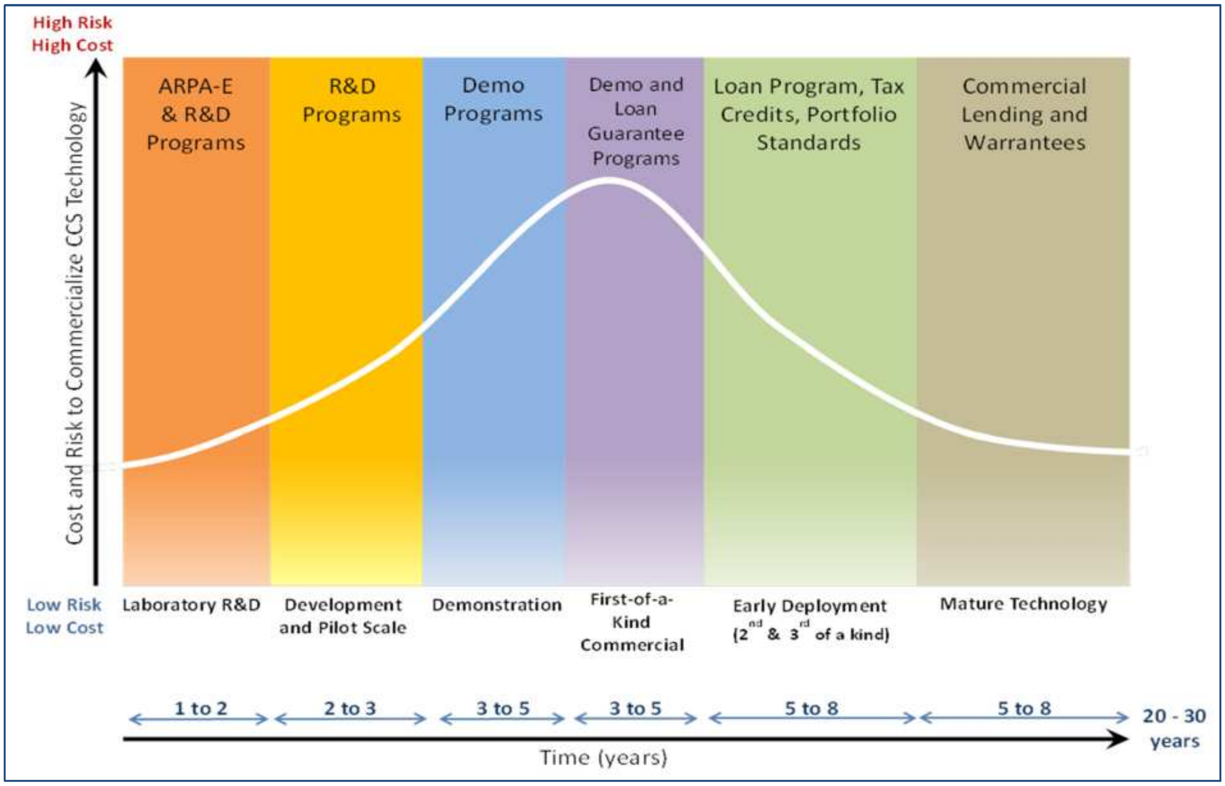
Once we capture $CO_2$, we must find a way to permanently sequester it.  The Roadmap outlines a program for $CO_2$ utilization and storage, which is an important effort to evaluate geologic $CO_2$ storage reservoirs, necessary to ensure there will be readily accessible storage facilities for $CO_2$ produced from the advanced power systems under development. The *Roadmap* includes a program to advance technologies in this area. The Regional Carbon Sequestration Partnerships ("RCSPs") and the CarbonSAFE Initiative are necessary for industry to advance technologies that will help grow our economy and increase our energy independence through the utilization of CO2, and for which low-cost, industrial sources of CO2 will be sought for enhanced oil and gas recovery. There are also niche opportunities to convert $CO_2$ into other products, including chemicals, fuels and cement that should be pursued with federal RD&D support.

Lastly, the *Roadmap* identifies a program for “breakthrough” technology advances that reflect “out-of-the-box” thinking for fundamentally new approaches to solving fossil fuel’s challenges. Examples of breakthrough technologies include the substitution of bio-systems for current chemical processes and $CO_2$ sorbents based on new human-made compounds. Support for these kinds of activities is consistent with RD&D supported through the DOE’s Advanced Research Projects Agency-Energy program or the fundamental research conducted in the applied energy programs at DOE.

## DEVELOPMENT EFFORTS IDENTIFIED IN THE ROADMAP

Early in the technology-development cycle, the technical risks for new energy technologies are incredibly high, particularly when moving an idea from concept designed on paper and turning that concept into an actual working technology. Not only are technologies at this stage a long way from commercialization, each phase of development carries significant technical risk. Since energy technologies are capital intensive, costs increase with each scale-up in development. Each of these factors makes it difficult to attract the private sector investment required to finance technologies at an earlier stage and even mid-stages of development, making federal support for scale-up stages of technology critical to attracting the necessary private sector cost-share. Given the timing of commercialization to achieve a return on investment for energy sector technologies, federal support at all of these stages is critical to successfully commercialize such technologies (see Figure 4 which graphically depicts the timeline for different phases of development of energy technologies).

**Figure 4 - Technology Development Timeline**[7]




The ultimate value of a new energy technology is generally not realized until several commercial-scale replications have occurred, which can take 20 years from concept to commercialization for large, capital-intensive energy systems. The good news is that the higher costs associated with new energy technologies can be reduced through learning by doing, which means the second-of–a-kind replication will cost less than the first.

New commercial-scale technologies cannot leap from a conceptual stage to commercial deployment in a single step. The *Roadmap* includes support of large-scale pilots for testing new technologies under real operating conditions at a scale beyond laboratory- and bench-scale, and before testing technologies in a commercial-scale demonstration. Large-scale pilot projects are mostly still early in the technology development timeline; the remaining time to commercialization and the risk that the process might not work at scale makes both commercial and internal financing often more challenging than either basic research or full-scale commercial-scale demonstrations. The success of technologies at the pilot scale can help to understand and overcome the risks inherent in early phase technology development and, if successful, encourage industry to make investments to advance the technologies to commercial implementation.

That is why federal support for the RD&D efforts outlined in the Roadmap is critical, as several of those are readying for large-scale pilot testing and a few are preparing for commercial demonstration. It is critical that a program for piloting and demonstrating these technologies be implemented for these technologies to be successfully commercialized. This means annual federal budgets must increase in the next several years to support the scale-up effort.

## PROJECTED BENEFITS OF THE ROADMAP

[7] CURC adaptation from EPRI TAG.

Successful implementation of the *Roadmap* can result in significant environmental, economic and energy security benefits for the U.S., including:

1. Further reduction of water use and air pollutants, including nitrogen oxides (NOx), sulfur dioxide ($SO_{2)}$, mercury (Hg) and particulate matter (PM) (see Figures 3 and 4 below);
2. Reduction of $CO_2$ emissions;
3. Production and preservation of affordable electricity essential for U.S. competitiveness through a diverse generation technology portfolio;
4. Enabling U.S. engineering and manufacturing expertise to grow, resulting in a robust U.S. supply chain and positioning the U.S. to be even more of a global leader in innovative fossil-fuel technologies;
5. Significant growth in gross domestic product (GDP) and jobs due to the macroeconomic impacts of increased domestic oil production and reductions in the cost of electricity (COE);
6. Improved energy security by:
    a. Generating affordable power for electricity consumers including increased industrial and advanced manufacturing customers;
    b. Improving the operational flexibility of existing and future generating plants to ensure continued electricity grid reliability and stability; and
    c. Using captured $CO_2$ as a commodity to recover crude oil, thereby increasing domestic oil production.

**Figure 5 - Emissions Reductions from New Coal Plants Projected in CURC-EPRI Roadmap**

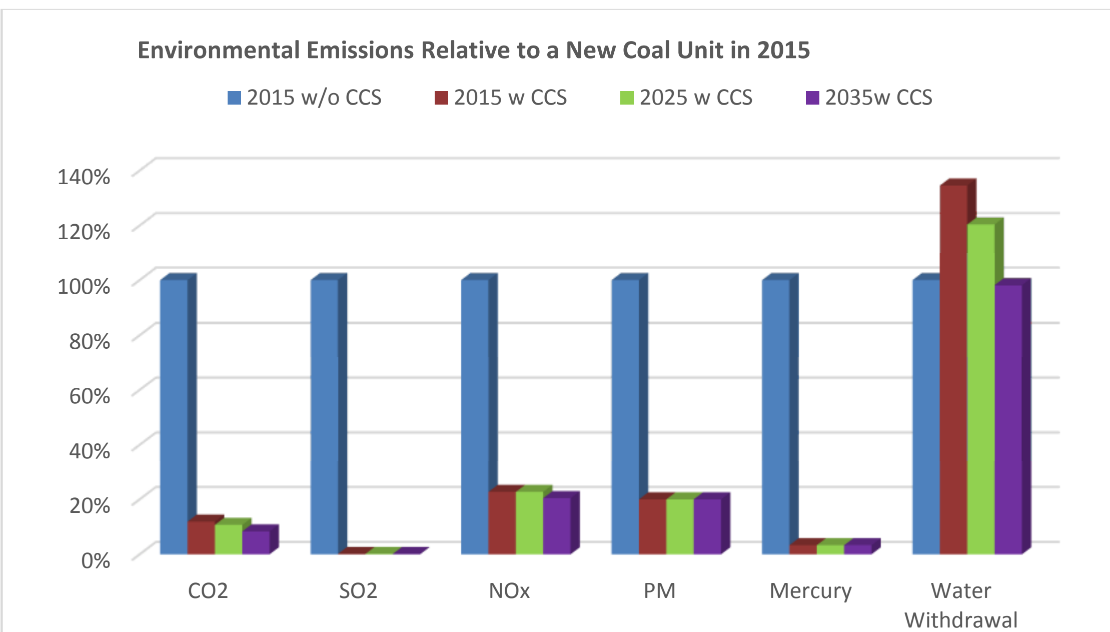
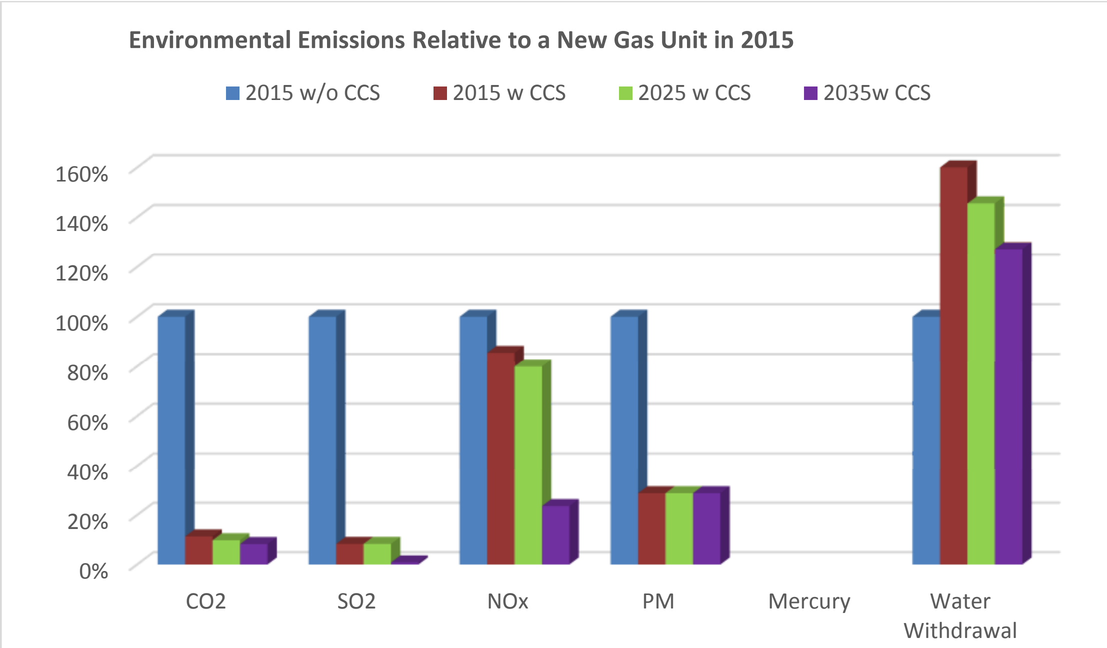


**Figure 6 - Emissions Reductions from a new Gas Unit Projected in the CURC-EPRI Roadmap**




If the RD&D outlined in the *Roadmap* is undertaken, the following COE projections are estimated with improved technology:

New Coal Unit with 90% Carbon Capture:

- 2030 – 20% reduction in COE compared to a new unit built with CCS in 2015
- 2040 – 40% reduction in COE compared to a new unit built with CCS in 2015

These projected cost improvements meet the cost reduction goals set by DOE in its 2013 Carbon Capture Technology Program plan for coal-based CCS systems.

New Natural Gas Unit with 90% Carbon Capture:

- 2030 – 15% reduction in COE compared to a new unit built with CCS in 2015
- 2040 – 30% reduction in COE compared to a new unit built with CCS in 2015

Concurrent with the release of the *2018 Roadmap*, CURC and the ClearPath Foundation published the results of a study that projects the macroeconomic benefits to the U.S. of new, lower-cost fossil energy technologies with CCUS as projected by the *2018 Roadmap*.[8] The study estimates that if an aggressive RD&D program is implemented that achieves the projected *Roadmap* cost targets, market-driven deployment of 62 to 87 GW of power-sector projects with installed carbon capture technologies for enhanced oil recovery can be enabled by 2040.

Under an aggressive RD&D scenario that achieves the CURC-EPRI cost targets, the macroeconomic impacts of $CO_2$ captured from the power sector for use in enhanced oil recovery (EOR) can:

[8] CURC and ClearPath Foundation, "Making Carbon a Commodity: the Potential of Carbon Capture RD&D," July 2018.

- Contribute up to 925 million barrels of annual domestic oil production
- Increase coal production for power by as much as 40% between 2020 and 2040
- Add 270,000 to 780,000 new jobs relating to increased oil production
- Result in a $70 to $190 billion increase in annual GDP by 2040.

The study also estimates that lower-cost electricity generated from low-cost carbon capture-enabled systems also yield significant macroeconomic benefits. Aggressive RD&D is estimated to reduce the retail COE up to 2.0% by 2040, which would increase annual GDP by $30 to $55 billion and create an additional 210,000 to 380,000 jobs.

## CONGRESSIONAL EFFORTS IN SUPPORT OF FOSSIL ENERGY RD&D

Since CURC and EPRI published their *2015 Roadmap*, we have witnessed growing support for policies that favor CCUS and the technology recommendations that achieve the overall *Roadmap* objectives, including a program for large-scale pilots. In FY 2017, Congress appropriated $50 million DOE to undertake a new, transformational coal pilot program, and has since appropriated an additional $60 million for the program (for a total of $110 million). The intent of the program solicitation is to design, construct and operate two large-scale pilots with transformational attributes. The DOE program has solicited projects for both processes and components, along with post-combustion carbon capture, aimed at enabling step-change improvements in coal-powered system efficiency, COE and carbon capture performance.[9] The program is being carried out in three phases, and CURC has recommended that the Congress provide an additional $25 million in FY 2020 to move into Phase 3 of the program.[10]

Previous energy legislation has included recommendations from prior *CURC-EPRI Roadmaps*, including the provisions of the Energy Policy Act of 2005, the Emergency Economic Stabilization Act of 2008, and more recently, comprehensive legislation that passed in the Senate but ultimately was not enacted at the end of the 114th Congress. In the 115th Congress, the first iteration of this Committee's Fossil Energy Research and Development Act (H.R. 5745) included provisions reflecting the recommendations of the *2018 Roadmap*. Similarly, legislation introduced last Congress by Senator Joe Manchin (D-WV), the Fossil Energy Utilization and Leadership (FUEL) Act (S. 2803), incorporated *CURC-EPRI Roadmap* recommendations.

In this Congress, Senator Manchin introduced the Enhancing Fossil Fuel Energy Carbon Technology (EFFECT) Act (S. 1201). That legislation builds on the FUEL Act and continues to incorporate recommended technology development pathways identified in the *2018 CURC-EPRI Roadmap*. The bill has bipartisan support and is cosponsored by Senator Lisa Murkowski (R-AK), Chairman of the Senate Energy and Natural Resources Committee, and would serve as a companion to the draft bill that this Committee has developed. CURC is appreciative of the Committee's leadership to reintroduce Fossil Energy Research and Development Act as it also continues to incorporate *CURC-EPRI Roadmap* recommendations that are critical to the development and deployment of the technology.

Lastly, while both CURC and EPRI developed the *Roadmap*, I am speaking only on behalf of CURC, and CURC is pleased to support legislation that will advance the *Roadmap* technology objectives.

CURC is pleased to support of the draft bill, the "Fossil Energy Research and Development Act of 2019", as it embodies the technology recommendations of the *2018 Roadmap.* We look forward to working with the Members of this Committee as you advance the legislation and to incorporate language that will address the effect of implementation of new technologies funded through this program for purposes of setting emissions standards.

[9] https://www.energy.gov/articles/department-energy-announces-50-million-large-scale-pilot-fossil-fuel-projects
[10] https://www.energy.gov/articles/department-energy-invest-65-million-large-scale-pilot-fossil-fuel-projects

Thank you for the opportunity to provide this testimony.

## APPENDIX

### Table 1 - Technology Programs Supported in the 2018 CURC-EPRI Roadmap

| | | |
|---|---|---|
| **Transformational Advanced Energy Systems** | | |
| Pressurized Oxy-Combustion (P-Oxy) | Coal and Natural Gas | Oxy-combustion power plants remove nitrogen from air cryogenically and perform the combustion of fossil fuels with oxygen and recycled flue gas to produce a stream largely comprised of $CO_2$ and water, greatly simplifying carbon capture. P-Oxy operates at elevated pressure, improving efficiency and allowing smaller components that combine to potentially reduce costs. |
| Chemical Looping Combustion (CLC) | Coal and Natural Gas | CLC is a form of oxy-combustion in which oxygen from air is separated using a metal oxide or limestone oxygen carrier, eliminating the need for cryogenic air separation and its significant energy penalty, while maintaining the relatively easy carbon capture provided by oxy-combustion. |
| Direct-Fired Supercritical $CO_2$ ($sCO_2$) Cycles | Coal and Natural Gas | A form of oxy-combustion, direct-fired $sCO_2$ cycles burn natural gas or syngas (provided by coal gasification) in a high-pressure oxy-combustor, producing very high-temperature $CO_2$ and water that drive a $sCO_2$ turbine to make power. Water and $CO_2$ (at pipeline pressure) are then removed downstream to conserve mass, producing a very-high-efficiency, potentially low-cost carbon capture system. |
| Indirect-Fired $sCO_2$ Cycles | Coal and Natural Gas | Replace steam-Rankine cycles with $sCO_2$ cycles which, due to the superior thermodynamic qualities of $CO_2$, have higher efficiency and utilize more compact turbomachinery. Can be used on any cycle that currently uses a steam-Rankine cycle, including solar thermal, geothermal, nuclear, biomass and any type of fossil fuel. The process results in higher efficiency and can be coupled with a low-cost carbon capture system. |
| Gasification | Coal | Coal can be gasified in either an air- or oxygen-blown gasifier to produce synthetic gas (syngas) that can be used in an efficient integrated gasification combined cycle system. Pre-combustion carbon capture can be added. New, highly efficient, compact gasifiers can be used in poly-generation plants that combine electricity generation with co-production of transportation fuels, fertilizer and/or other chemicals to improve the overall economics. |
| Compact Hydrogen Generator | Natural Gas | New, highly efficient method for producing hydrogen (alternative to steam-methane reforming). |
| **Cross-Cutting Technologies** | | |
| A-USC Materials | Coal and Natural Gas | A-USC materials are needed to allow working fluid temperatures up to 760°C to support highly efficient combustion and heat exchange systems for both steam-Rankine and $sCO_2$ power systems and other high-temperature technologies. Can be applicable to both new and existing plants. |
| Turbines | Coal and Natural Gas | RD&D and testing of steam turbines, combustion turbines, and $sCO_2$ turbines and pressure-gain combustion, all in an effort to improve efficiency, reliability and |

| Transformational Advanced Energy Systems | | |
|---|---|---|
| | | flexibility and support power systems evaluated in the Roadmap. |
| $CO_2$ Capture | Coal and Natural Gas | Advances in solvents, sorbents and membranes for both pre- and post-combustion carbon capture focused on lowering energy requirements and overall cost of capture. Technologies will need to be adjusted to handle the differences between coal and natural gas flue gas, which include different $CO_2$ concentrations and trace species. |
| $CO_2$ Storage | Coal and Natural gas | Saline reservoirs, enhanced oil and gas recovery, and other geologies are being explored for storing $CO_2$ both onshore and offshore. RD&D as well as large-scale $CO_2$ storage and regional infrastructure strategies related both to storage and transportation in the U.S. are needed |
| Existing Plants | Coal and Natural Gas | RD&D to support flexibility and reliability of operations of existing plants |
| Cross-Cutting | Coal and Natural Gas | RD&D on technologies that support all Roadmap areas, including:<br>• Advanced manufacturing<br>• Breakthrough technologies<br>• Sensors and controls<br>• Water management |

# Shannon Angielski

**Principal, Governmental Affairs, Van Ness Feldman**

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Shannon Angielski is a principal at Van Ness Feldman LLP, a Washington D.C. based law firm that specializes in energy, environment and natural resource policy and law, and serves as the Executive Director of the Carbon Utilization Research Council (CURC). CURC is a coalition of producers, electric utilities that rely upon coal and natural gas for electricity production, gas distributors, equipment manufacturers and technology innovators, national associations, and state, university and technology research organizations (see www.curc.net). Members of CURC coalesce around the need for technology solutions to ensure the responsible use of our fossil energy resources in a balanced, low carbon generation portfolio. They serve this mission by evaluating technology development needs, developing policies and public-private programs to advance technology solutions, and by advocating for the advancement of those policies with policymakers, NGOs and other stakeholders. Advancing carbon capture, utilization and storage is a key component of the policy portfolio that CURC serves.

Shannon earned her M.S. in Environmental Science and Public Policy from Johns Hopkins University in 2000 and her B.A. in Political Science and International Affairs from the University of New Hampshire in 1994. She is a member of the National Coal Council, and serves on the board of the Washington Coal Club.

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