Testimony of Shannon Angielski

Executive Director

Carbon Utilization Research Council (CURC)

Before the

Committee on Energy & Commerce

Subcommittee on Environment and Climate Change

Hearing on "Building America's Clean Energy Future: Pathways to Decarbonize the Economy"

CURC Testimony:

"Contribution of Fossil Fuel Technology Innovation to Deep Decarbonization Objectives"

Washington, D.C.

July 24, 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 electric utilities and power generators that rely upon diverse sources for their electricity production, including natural gas and coal, and that own their own natural gas distribution companies, equipment manufacturers and technology innovators, national associations that represent the power generating industry, labor unions, coal producers, and state, university and technology research organizations. Members of CURC believe that American fossil fuels and ingenuity in technology innovation will satisfy the world's growing appetite for affordable energy, improve energy security, improve trade by increasing 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 industries and partnering with the Department of Energy to develop and commercialize technologies that will transform how the world uses fossil fuels. Successfully achieving these objectives will require a robust and sustained set of policies to incentivize the development and deployment of low and zero-carbon fossil energy technologies that are necessary to achieve global climate targets and that can also contribute to a robust U.S. economy.

On behalf of CURC, I am pleased to testify before the House Energy & Commerce Committee, Subcommittee on the Environment and Climate Change, to discuss efforts to decarbonize the U.S. economy. Given the nature of CURC and our mission, my testimony will focus on technology innovation efforts to decarbonize the use of fossil fuels in the power sector, particularly with respect to carbon capture, utilization and storage, and how those efforts can be leveraged with other industrial uses of fossil fuels. Throughout my testimony, please note that I refer to carbon capture, utilization and storage as either "CCUS" or carbon capture, and carbon dioxide as carbon or CO_2.

I will address five key points in my oral testimony, and will reserve broader discussion on these points in my written testimony:

(1) The growing use of fossil fuels must be accompanied by robust innovation in carbon capture, utilization and storage in the production and use of fossil fuels in order to meet deep, de-carbonization objectives.
(2) Fortunately, the U.S. knows how to capture carbon, use it to produce valuable products, and store it in an abundance of well documented and studied geologic reservoirs.
(3) While carbon capture is in the early stages of deployment today, the U.S. is making significant strides to reduce costs and create a robust carbon capture industry.
(4) Investments in carbon capture will benefit the environment, improve energy security, and provide macroeconomic benefits to the U.S. economy.
(5) Carbon capture is bipartisan and industry agnostic. With robust and sustained policy support, carbon capture can contribute to any deep decarbonization goals.

The growing use of fossil fuels must be accompanied by robust innovation in carbon capture, utilization and storage in the production and use of fossil fuels. Global fossil fuel use is on the rise is projected to rise well into the future due to the important role fossil fuels play in providing affordable, reliable and low-cost energy. All modeling that has been conducted by international authorities, including the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA), agree that carbon capture, utilization and storage is an integral part of the technology solution set in order to cost-effectively achieve global climate targets. Recent analysis from IEA estimates that by 2060, CCUS accounts for approximately 100 gigatons of CO_2 emissions reductions to meet the goals of the 2°C scenario. [1] To put this scale of emissions reductions into perspective, this would be the same as roughly 1,100 coal units (500 MW in size) or 3,200 natural gas combined cycle units (500 MW in size) – or some combination of the two – installing CO_2 capture systems by 2030 and operating those systems for the next 30 years.[2] To date, CCUS has not been deployed at the rate needed to achieve this, which means CCUS development and deployment must be accelerated to meet any domestic or global deep decarbonization objectives.

At high capture rates, and/or when combined with sustainable biofuels, power generated from fossil fuels can achieve net zero carbon emissions, which is important to the broader discussion of achieving deep decarbonization from dispatchable grid technologies. Modeling also shows that in order to achieve deep decarbonization goals, CCUS must be complimented with technologies such as direct air capture and negative emissions technologies.

Fortunately, the U.S. knows how to capture carbon, use it to produce valuable products, and store it in an abundance of well documented and studied geologic reservoirs. Projects already operating in the U.S. capture roughly 25 million metric tons of CO_2 annually from industrial processes,[3] transport large volumes of CO_2 via a 4,500 mile pipeline network and store it in a variety of geologies across the country – in fact, companies have been doing this for nearly 50 years to enhance oil recovery, and for about 15 years in partnership with the U.S. Department of Energy (DOE) in other geologies like saline aquifers. In order to deploy more CCUS projects and increase the volume of captured CO_2, projects need to integrate all of those elements all together into one system. The PetraNova project that retrofit a coal power plant with carbon capture in Texas, and the Archer Daniels Midland ethanol production facility with carbon capture project in Illinois, are but two prime examples of how to integrate those different industry processes together into one project and demonstrate that carbon capture, utilization and storage is technically feasible.

While carbon capture is in the early stages of deployment today, the U.S. is making significant strides to reduce costs and create a robust carbon capture industry. The reason why there are not more CCUS projects operating is because each project is associated with higher costs, despite carbon capture being a relatively cost-competitive way to reduce emissions in many industries today. Thankfully innovative research and development is well underway that will further improve the cost and performance of new carbon capture technologies through the DOE's world class carbon capture and storage programs. These technologies have the promise of providing dispatchable fossil fuel power generation with low- to

---

[1] CCUS in the global energy context, presentation by Samantha McCulloch, Head of CCUS, International Energy Agency, 25th March 2019, http://www.curc.net/webfiles/Briefing%20Series/Briefing%20%231/McCulloch%20-%2028%20March%20CCUS%20Briefing.pdf

[2] This calculation assumes the coal plant operates at 75% capacity factor, the natural gas combined cycle plant at 60% capacity factor, and each with a 90% capture rate.

[3] "Global Status of CCS", 2018, Global CCS Institute

zero-carbon emissions necessary to support the growth of renewables and achieve deep decarbonization of the power grid. These novel power cycles are designed to facilitate the capture of CO_2 at a lower energy penalty and cost than conventional methods. There are also advances in post-combustion carbon capture - which can be retrofit to the world's existing infrastructure, much of which is relatively young - that can lower the cost of capture. If this technology innovation is coupled with robust and sustained deployment policies, the technology will follow a well understood cost reduction curve and economies of scale will be achieved in the same way this happened with the wind and solar industries. Importantly, carbon capture is fuel and emissions agnostic; the technology can capture CO_2 molecules emitted from oil, coal and natural gas combustion, as well as from other sources such as ethanol production and even from the air. Investments in power sector applications of carbon capture will also benefit the use of these technologies in other industries and when applied to other fuel gas streams because the fundamental science is generally the same, regardless of the source of CO_2. This technology has broad applications and with leveraged and targeted investments, can have a significant economic and environmental impact.

Investments in carbon capture will benefit the environment, improve energy security, and provide macroeconomic benefits to the U.S. economy. Analysis conducted by CURC and ClearPath Foundation shows that under a wide range of scenarios, there are significant economic benefits to the U.S. if public-private sector investments in carbon capture are undertaken under a wide range of scenarios. Our analysis projects at least 17 GW and 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.

Carbon capture is bipartisan and industry agnostic. With robust and sustained policy support, carbon capture can contribute to any deep decarbonization goals. Enactment of the reformed 45Q carbon sequestration tax credits is one measure of bipartisan support; a broad number of industries can implement carbon capture with the 45Q credits. 45Q is a key policy tool for catalyzing a carbon capture industry in this country and is seen as a model policy by international energy entities. This policy will lower the cost of implementing carbon capture by providing a tax credit for every metric ton of CO_2 that is captured from any qualified industrial processes and stored in geologic reservoirs including oil reservoirs, or when the CO_2 is converted into other products like chemicals or used in cement production. Several carbon capture projects are in development as a result of this policy. Project developers are eagerly awaiting issuance of Treasury guidance to understand how to be eligible for the tax credits in order for investments to flow into projects and meet the commence construction deadline to claim the 45Q tax credits. For the record, there are concerns that project developers are already up against the statutory commence construction deadline, and to ensure this tax credit can be used in the way it was intended by Congress, it will be necessary to extend that deadline.

Even as the U.S. continues to invest in the public-private partnership for research, development and demonstration of carbon capture, and in projects that will be incentivized from the 45Q tax credits, it is important to recognize that additional policy tools will help to accelerate and attract investment in carbon capture projects in the same way Congress enacted several policy tools that resulted in the commercialization of other nascent energy technologies.

Several bills have been introduced that would put into place these policies and help to reduce the costs of implementing carbon capture in some industries. Some of those include:

- the "Utilizing Significant Emissions with Innovative Technologies" or "USE IT" Act (S. 383 / H.R. 1166), which would invest in carbon utilization and direct air capture research as well as streamline carbon capture and CO_2 pipeline infrastructure to help catalyze a CCUS industry;
- the "Carbon Capture Modernization Act" (S. 407 and H.R. 1796) which would modify the tax credit requirements to unlock nearly $2 billion in existing investment tax credits for carbon capture retrofits in the power sector;
- new authorizations to update the federal RD&D funding programs for carbon capture for fossil fuel power generation and for industrial capture through the "Fossil Energy Research and Development Act" (H.R. 3607) and the "Enhancing Fossil Fuel Energy Carbon Technology" or "EFFECT" Act (S. 1201); and
- two bills that would make carbon capture projects eligible for master limited partnerships (the "Financing Our Future Energy Act", (S. 1841 / H.R. 3249)), and private activity bonds (the "Carbon Capture Improvement Act" (S. 1763)) which are designed to lower the cost of financing of carbon capture projects.

These are just some examples of the bills before Congress with bipartisan support that would complement the existing 45Q tax credit program. CURC welcomes the opportunity to work with this Committee in the evaluation of these policies and in the design of other policies that may be within the jurisdiction of this Committee to incentivize the development and deployment of carbon capture technology.

Conclusion. I want to close by saying the world is watching as we embark on these initiatives. U.S. investment in clean energy technologies, including those for coal, has resulted in the development and deployment of technologies that are in use all over the world today. Federal investments in all forms of clean energy have been a major return on the investment for both the U.S. economy and the global environment. As the U.S. continues to invest in carbon capture, we will benefit not only from cleaner power that is necessary to meet any deep decarbonization objectives, but also from new markets for U.S. technologies both domestically and abroad. Investment in CCUS technology will transform carbon dioxide into an economic resource, lower the cost of reducing emissions, create jobs, save consumers money, safeguard the environment, and demonstrate that the technology can be used here as well as around the world.

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 electric utilities and power generators that rely upon diverse sources for their electricity production, including natural gas and coal, and that own their own natural gas distribution companies, equipment manufacturers and technology innovators, national associations that represent the power generating industry, labor unions, coal producers, and state, university and technology research organizations. Members of CURC believe that American fossil fuels and ingenuity in technology innovation will satisfy the world's growing appetite for affordable energy, improve energy security, improve trade through increasing 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 industries and partnering with the Department of Energy to develop and commercialize technologies that will transform the way the world uses fossil fuels. Successfully achieving these objectives will require a robust and sustained set of policies to incentivize the development and deployment of low and zero-carbon fossil energy technologies that are necessary to achieve global climate targets and that can also contribute to a robust U.S. economy.

On behalf of CURC, I am pleased to testify before the House Energy & Commerce Committee, Subcommittee on the Environment and Climate Change, to discuss efforts to decarbonize the U.S. economy. Given the nature of CURC and our mission, my testimony will focus on technology innovation efforts to decarbonize the use of fossil fuels in the power sector, particularly with respect to carbon capture, utilization and storage, and how those efforts can be leveraged with other industrial uses of fossil fuels. Throughout my testimony, note that I refer to carbon capture, utilization and storage as either "CCUS" or carbon capture, and carbon dioxide as carbon or CO_2.

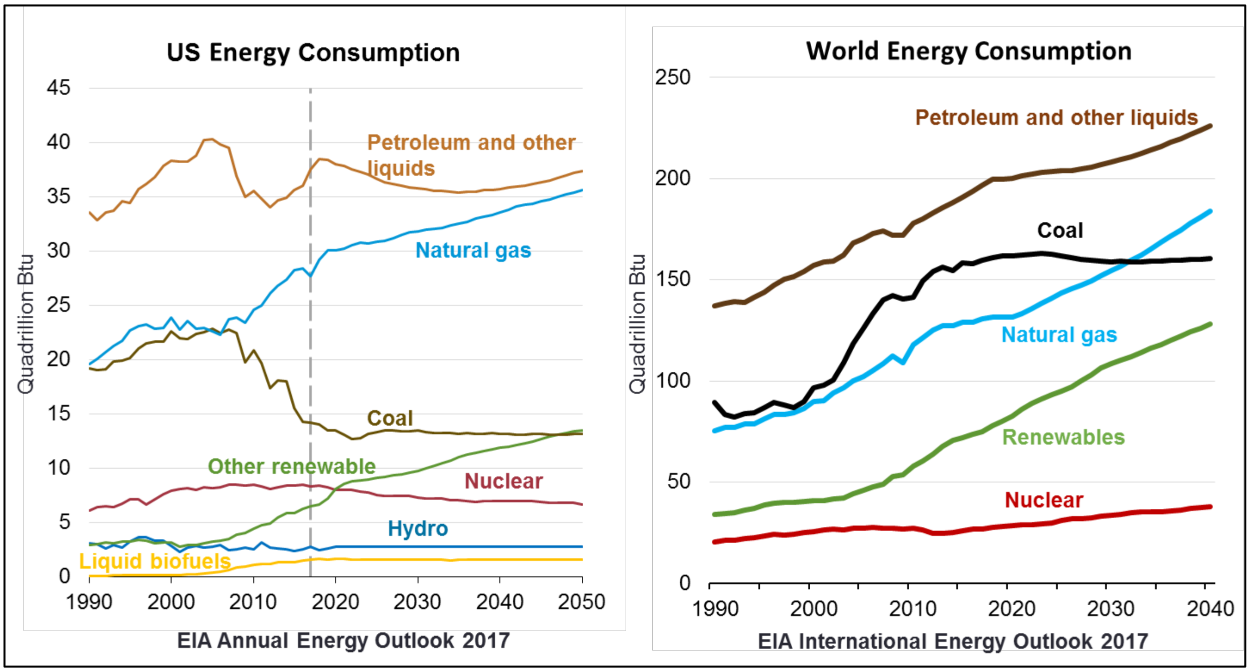
CURC's testimony will address five key points:

(1) The growing use of fossil fuels must be accompanied by robust innovation in carbon capture, utilization and storage in the production and use of fossil fuels in order to meet deep, de-carbonization objectives.
(2) Fortunately, the U.S. knows how to capture carbon, use it to produce valuable products, and store it in an abundance of well documented and studied geologic reservoirs.
(3) While carbon capture is in the early stages of deployment today, the U.S. is making significant strides to reduce costs and create a robust carbon capture industry.
(4) Investments in carbon capture will benefit the environment, improve energy security, and provide macroeconomic benefits to the U.S. economy.
(5) Carbon capture is bipartisan and industry agnostic. With robust and sustained policy support, carbon capture can contribute to any deep, decarbonization goals.

(1) THE GROWING USE OF FOSSIL FUELS MUST BE ACCOMPANIED BY ROBUST INNOVATION IN CARBON CAPTURE, UTILIZATION AND STORAGE IN THE PRODUCTION AND USE OF FOSSIL FUELS.

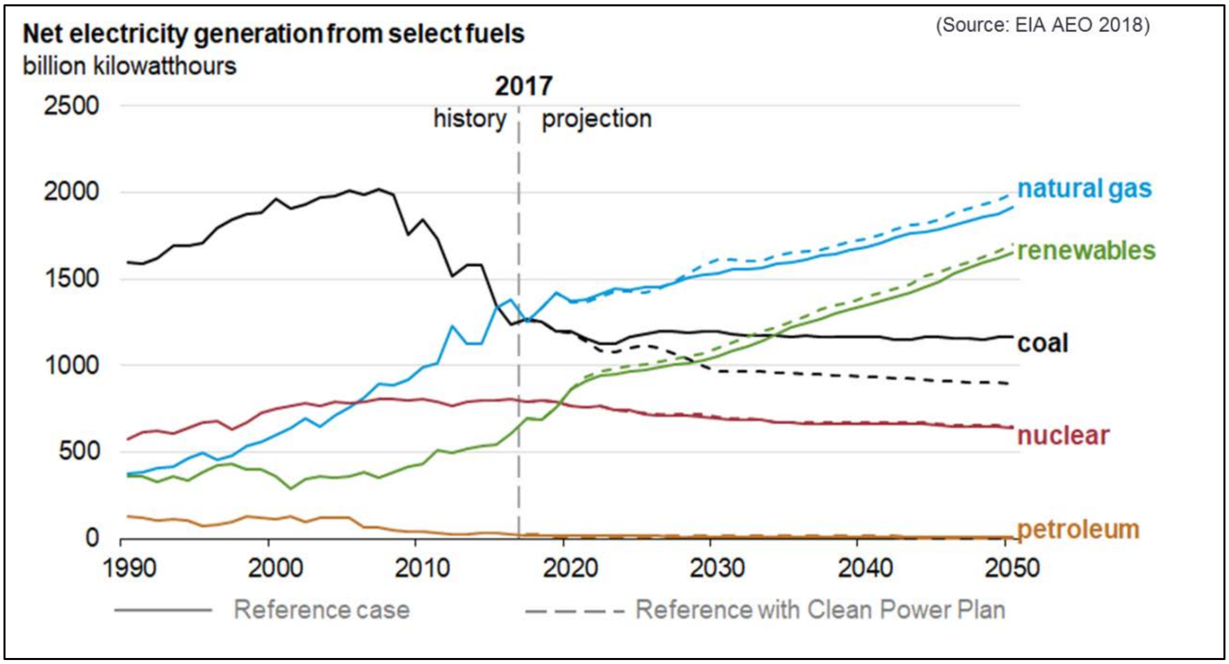
Domestically, fossil fuels comprised 80% of total U.S. energy consumption[4] and 63.5% of net electricity generation[5] in 2018. The U.S. Energy Information Administration (EIA) estimates that coal and natural gas will provide 58% of total U.S. net electricity generation in 2040[6] (see Figures 1 and 2). Globally, consumption of coal and natural gas are projected to provide 45% of energy consumption in 2030 and will grow to nearly 50% of global consumption by 2040 (see Figure 1).

Figure 1 - U.S. and World Energy Consumption[7]



[4] EIA Today in Energy, April 16, 2019. https://www.eia.gov/todayinenergy/detail.php?id=39092
[5] EIA FAQ, Updated March 1, 2019. https://www.eia.gov/tools/faqs/faq.php?id=427&t=3
[6] EIA 2019 Annual Energy Outlook. https://www.eia.gov/outlooks/aeo/pdf/appa.pdf
[7] EIA Annual Energy Outlook 2017, EIA International Energy Outlook 2017.

Figure 2 - U.S. Electricity Generation Projections[8]



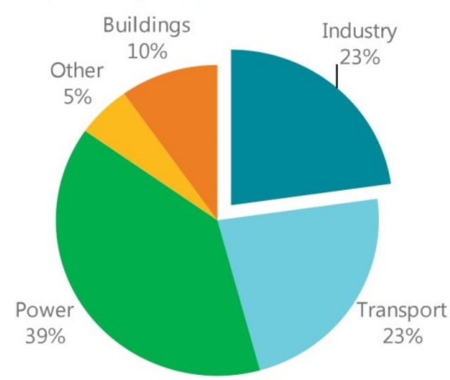
While the U.S. EIA projects coal consumption will decline, EIA also projects it will still stabilize and continue to represent a major portion of electricity generation through 2050. That decline is offset by increased use of natural gas. Similarly, the International Energy Agency (IEA) projects global coal consumption will continue to increase before stabilizing, but global coal consumption does not decrease through 2050. Globally, oil and natural gas consumption will increase to more than double their consumption rates today. All of these fuels are projected to increase in use because they are widely available in emerging countries and economies, low cost, and abundant. No matter whether using coal, oil or natural gas, each fuel source significantly contributes to global energy and economic growth, and emits CO_2 without the use of carbon capture abatement technologies.

[8] U.S. EIA Annual Energy Outlook 2018.

As shown in Figure 3, the point sources attributable to those emissions come from electricity and steam production, cement, iron and steel, biofuels and biopower production, and other industrial sources. These industries are critical for economic growth and stability, and to support a growing global population, and cannot simply be eliminated. While some of these industrial processes can be electrified, many (e.g. steel production, some chemicals production, etc.) require the use of fossil fuels. This is because the energy demand for these industry sectors is high-temperature heat, for which there are few alternatives to the direct use of fossil fuels. And while some industries can be electrified, some cannot. In addition, dispatchable fossil power generation with CCUS will still be needed to provide a source of electricity. The good news is that carbon capture technology can help reduce and even eliminate the emissions of CO_2 from those sources.

Figure 3 – Global CO_2 Emissions from Different Economic Sectors[9]

Figure 3. Direct CO_2 emissions by sector, 2017



Source: IEA (2019).

In order to meet deep decarbonization objectives, technologies must be developed and deployed to reduce the carbon footprint from the growing use of fossil fuels. Several international models, including the United Nations International Panel on Climate Change (UNIPCC) and the IEA, show the need for CCUS technology to significantly reduce CO_2 emissions in order to meet global climate targets (see Figure 4).

[9] Transforming Industry through CCUS, May 2019, International Energy Agency

Figure 4 - Importance of Technology in Meeting Global Climate Targets

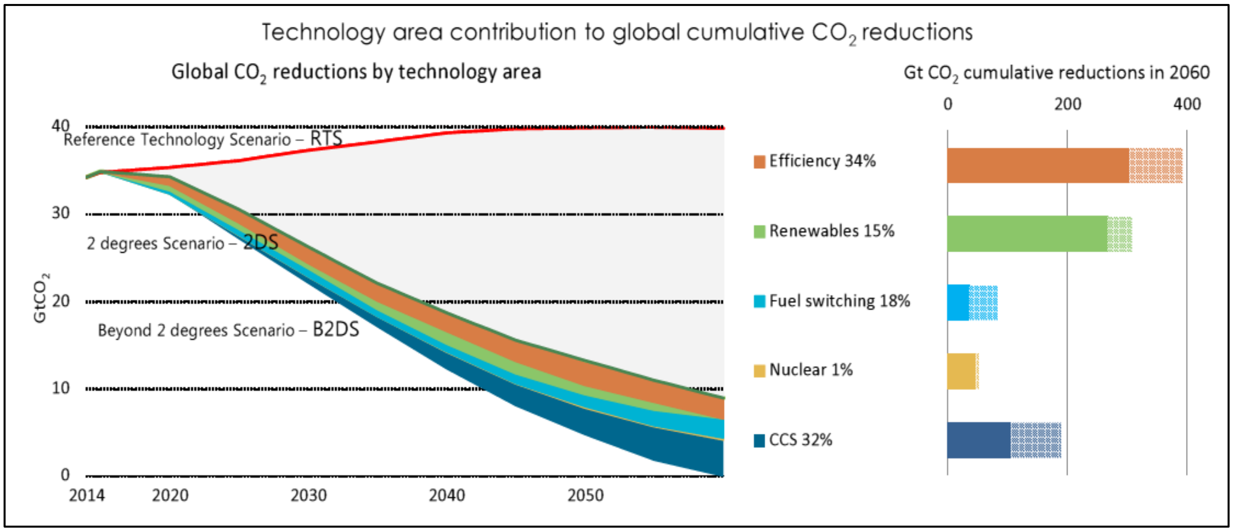


Figure 4 from IEA shows the critical role that CCUS plays with increasing climate ambition. [10] By 2060, CCUS accounts for approximately 100 gigatons of CO_2 emissions reductions necessary to meet the goals of the 2°C scenario. To put this scale of emissions reductions into perspective, this would be the same as roughly 1,100 coal units (500 MW in size) or 3,200 natural gas combined cycle units (500 MW in size) – or some combination of the two – installing CO_2 capture systems by 2030 and operating those systems for the next 30 years.[11] To date, CCUS has not been deployed at the rate needed to achieve either of these targets, which means CCUS development and deployment must be accelerated to meet any domestic or global deep decarbonization objectives.

At higher capture rates and/or when combined with sustainable biofuels, power generated from fossil fuels can achieve net zero carbon emissions, which is important to the broader discussion of achieving deep decarbonization from dispatchable grid technologies.[12] Modeling also shows that in order to achieve deep decarbonization goals, CCUS must be complimented with technologies such as direct air capture and negative emissions technologies.

---

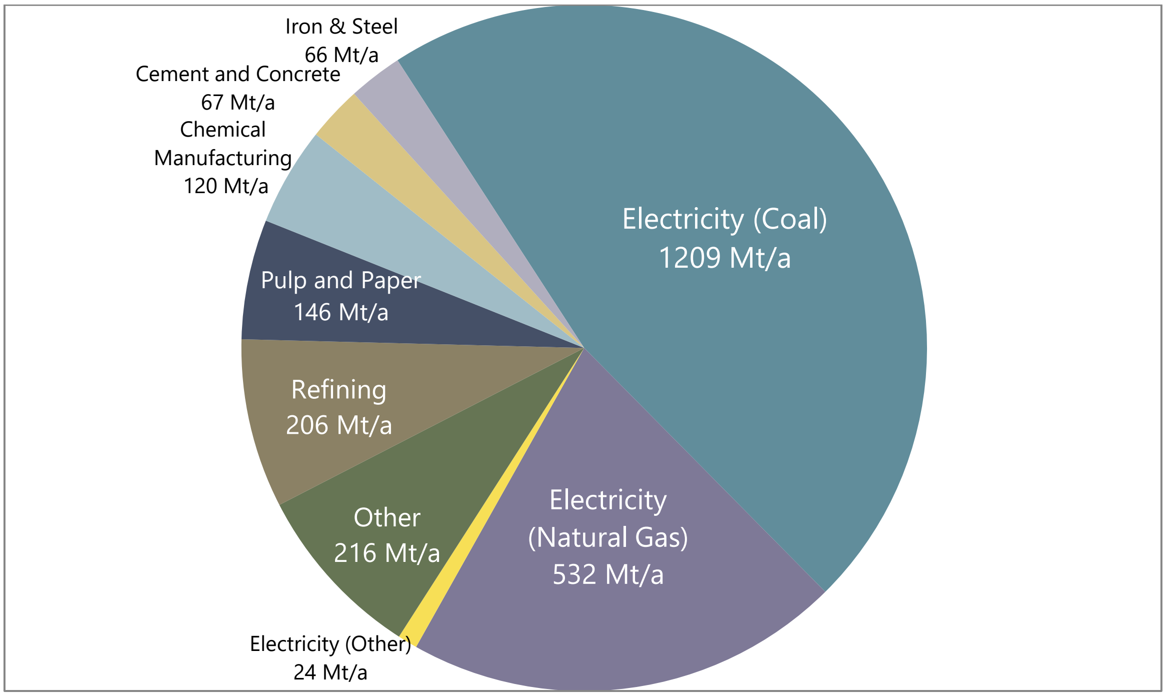
[10] CCUS in the global energy context, presentation by Samantha McCulloch, Head of CCUS, International Energy Agency, 25th March 2019, http://www.curc.net/webfiles/Briefing%20Series/Briefing%20%231/McCulloch%20-%2028%20March%20CCUS%20Briefing.pdf

[11] This calculation assumes the coal plant operates at 75% capacity factor, the natural gas combined cycle plant operates at a 60% capacity factor, and each has a 90% capture rate.

[12] Towards Zero Emissions in Power Plants Using Higher Capture Rates or Biomass, IEA GHG Technical Report 2019-02, March 2019, IEA Greenhouse Gas R&D Programme.

Nearly 75% of U.S. of point source CO_2 emissions are from electric power sector. In 2017, approximately 2.6 Gigatons of CO_2 were reported to the U.S. Environmental Protection Agency (EPA) as being emitted from industrial point sources in the U.S. Figure 5 shows the breakdown of CO_2 emissions reported to the EPA Greenhouse Gas Reporting Program in 2017. The U.S. electric power sector is where the most significant reductions can occur.

Figure 5 - U.S. CO_2 Emissions by Sector (2017)[13]

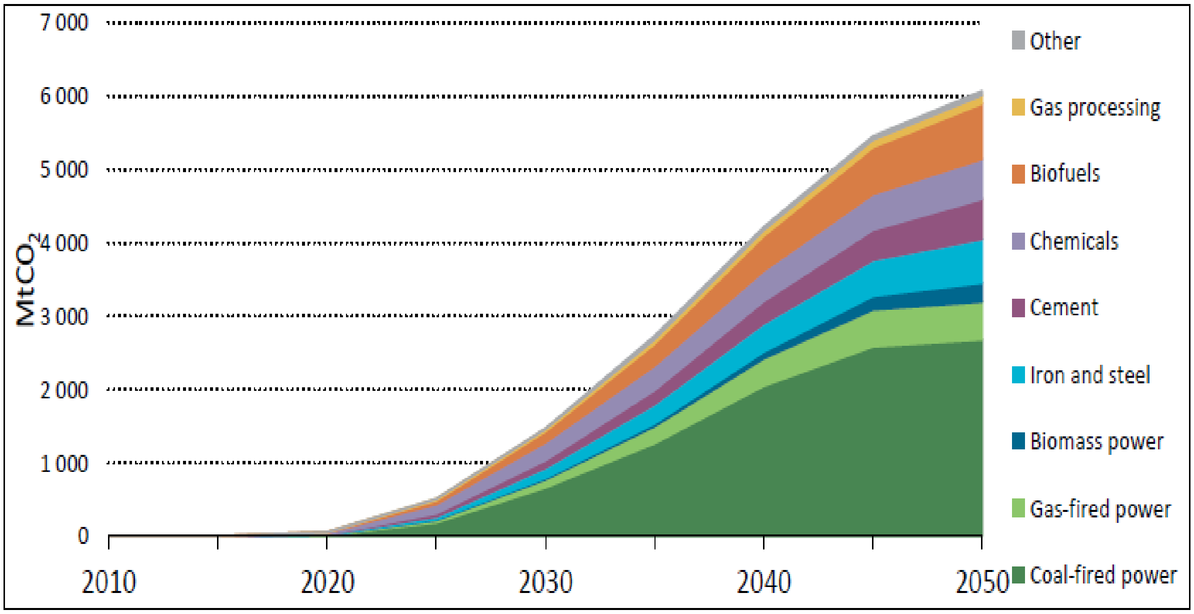


IEA estimates that the power sector accounts for approximately 39% of global CO_2 emissions, so the impact of carbon capture in reducing emissions from the power sector will be significant (see Figure 3 above).

[13] U.S. EPA GHGRP 2017 data by point sources (https://www.epa.gov/ghgreporting)

Globally, the IEA projects that a significant amount of carbon capture deployment will be needed for natural gas and coal power generation in order to achieve global climate targets (see Figure 6), contributing to nearly 50% of the CO_2 emissions reductions from carbon capture across industry sectors. This is largely driven by increasing coal use mostly for power generation in Asia and China, where the coal fleet is very young and continues to grow.[14]

Figure 6 - Global Carbon Capture by Industry to Achieve 2° Scenario[15]



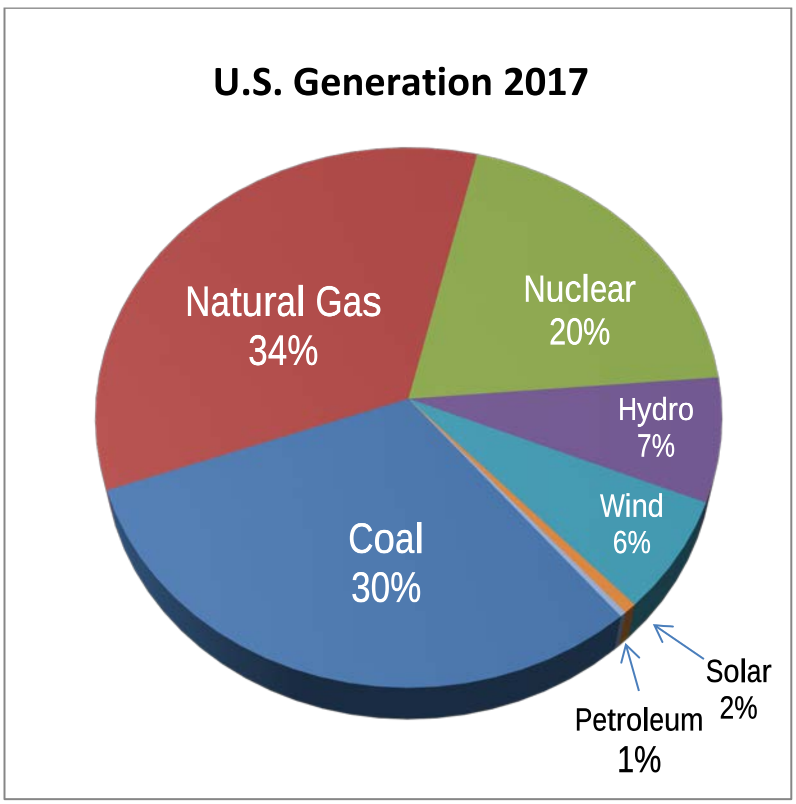
Source: Derived from *Energy Technology Perspectives 2016 (IEA, 2016)*.

[14] CCUS in the global energy context, presentation by Samantha McCulloch, Head of CCUS, International Energy Agency, 25th March 2019, http://www.curc.net/webfiles/Briefing%20Series/Briefing%20%231/McCulloch%20-%2028%20March%20CCUS%20Briefing.pdf

[15] International Technology Perspectives 2016, IEA.

In order to achieve deep decarbonization on the power grid, dispatchable fossil fuel power generation with carbon capture will be necessary to ensure a balanced, cost-effective, and reliable electric generation portfolio. Today coal and nuclear together provide 50% of our electricity and represent over 60% of total installed generating capacity (See Figure 7). Low cost natural gas has resulted in some natural gas combined cycle (NGCC) systems transitioning to baseload operation, whereas historically, due to higher gas prices, those units were load following due to their ability to readily ramp up and down in response to changes in power demand. In addition to NGCC becoming more widespread, federal and state financial incentives and policies have helped the deployment of renewables that, with a number of deployments, have come down in market price. As the existing coal fleet is on average, 45 years of age, it will be important to invest in low- and zero-carbon fossil generating technologies that can provide low cost, dispatchable power to ensure a balanced generating portfolio can be sustained and provide benefits in the future. A balanced generating portfolio will help to avoid prices spikes in fuel costs, mitigate against weather impacts, balance the intermittency of wind and solar resources, and protect consumers from higher electricity costs.

Figure 7 - U.S. Generation 2017[16]



[16] U.S. EIA Annual Energy Outlook, 2018

(2) FORTUNATELY, THE U.S. KNOWS HOW TO CAPTURE CARBON, USE IT TO PRODUCE VALUABLE PRODUCTS, AND STORE IT IN AN ABUNDANCE OF WELL DOCUMENTED AND STUDIED GEOLOGIC RESERVOIRS.

The U.S. already captures CO_2 from a variety of industrial processes. For example, CO_2 is separated and captured in the oil refining industry to produce gasoline, and small volumes of CO_2 are captured from power generation facilities to use in carbonated beverages and other products. These are but some examples of how CO_2 is captured and used in the U.S. today. U.S. industry also has expertise in transporting CO_2 with over 4,500 miles of CO_2 pipelines that move CO_2 around the nation today. Much of that CO_2 is used to enhance oil and gas recovery, and a significant amount of that CO_2 becomes trapped and securely stored in those oil and gas reservoirs. This has been done by the industry for nearly 50 years.

The U.S. has been a leader in the development of CCUS technology aided by the DOE's world class carbon capture and storage programs. Through the DOE carbon storage program, we have been storing large volumes of CO_2 in a variety of geologic reservoirs to prove out their ability to safely and effectively store CO_2. In addition, the DOE program is responsible for supporting the demonstration of carbon capture in a variety of industrial sectors. 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. This plant is integrating all of these processes into one project, and has captured over 2.5 million metric tons of CO_2, transporting it via an 82 mile pipeline to an oil field where the CO_2 is used to recover oil and securely stored in the oil reservoir.[17]

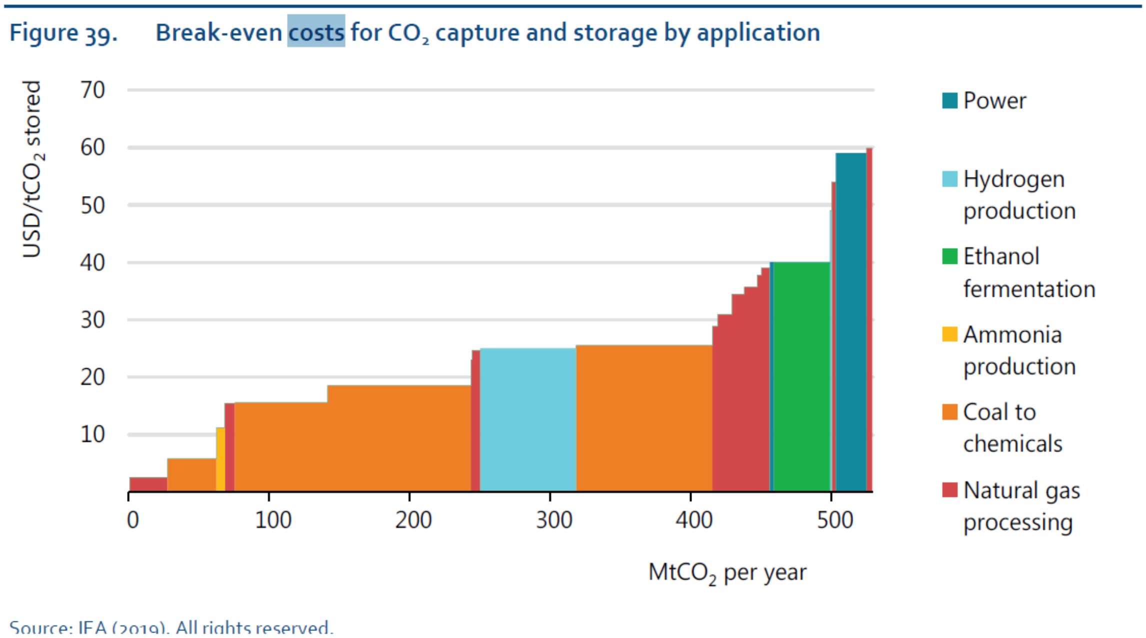
While the U.S. has an experienced industry and existing infrastructure to support the growth of a carbon capture industry, significantly larger volumes of CO_2 need to be captured, transported and stored at large-scale in order to achieve climate objectives.

(3) WHILE CARBON CAPTURE IS IN THE EARLY STAGES OF DEPLOYMENT TODAY, THE U.S. IS MAKING SIGNIFICANT STRIDES TO REDUCE COSTS AND CREATE A ROBUST CARBON CAPTURE INDUSTRY.

Recent analysis from the IEA indicates that while CCUS may be a competitive decarbonization solution for some industrial processes, such as gas processing, carbon capture projects remain expensive in some industries, including the power sector (see Figure 8). Thankfully, innovative research and development is underway to improve the cost and performance of new carbon capture technologies through DOE carbon capture and storage programs. The technologies in the DOE program portfolio have the promise of providing low- to zero-carbon, dispatchable power needed to support the growth of renewables and achieve the deep decarbonization goals for the U.S. power grid.

[17] https://www.nrg.com/case-studies/petra-nova.html and http://curc.net/webfiles/CCS%20101%20Briefing%20Series/Briefing%20%234/Update%20on%20DOE%20CCUS%20Program_6-25-2019.pdf

Figure 8 - Costs of CO2 Capture and Storage by Industry Application[18]



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 a "technology roadmap". Last summer, CURC and EPRI published the "2018 Advanced Fossil Energy Technology Roadmap" which identifies pathways to accelerate the development of fossil fuel generating options that include carbon capture, as the window for achieving transformational improvements in dispatchable generation is closing.[19] 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, the time between now and 2030 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- and zero-carbon emissions technologies that are cost competitive in the electricity market will be required to supply the dispatchable replacement capacity necessary to achieve deep de-carbonization of the electric grid.

The 2018 Roadmap 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. This includes a future generation fleet that will meet global decarbonization objectives. The Roadmap outlines several RD&D pathways for both new and existing coal and natural gas

[18] "Transforming Industry through CCUS", May 2019, International Energy Agency
[19] "CURC-EPRI Advanced Fossil Energy Technology Roadmap" July 2018, http://curc.net/curc-epri-advanced-technology-roadmap-1

technologies that can provide a suite of low- and zero-carbon, fossil fuel platforms capable of being cost competitive with other forms of electricity generation in future electricity markets.

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 (see Appendix). 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 including low- or zero-carbon emissions, efficiency, flexibility, environmental performance and cost from the use of fossil fuels.

The novel power cycles identified in the 2018 Roadmap are designed to facilitate the capture of CO_2 at a lower energy penalty and cost than conventional methods. Example technologies 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 considers carbon capture development paths for solvents, sorbents and membranes as well as hybrid approaches 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 and natural gas combined cycle power plants. ***Importantly, our analysis determined that many technologies for carbon capture 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, as well as for other industrial applications of the technology.***

The Roadmap also 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 2018 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 CO_2, and for which low-cost, industrial sources of CO_2 will be sought for enhanced oil and gas recovery. The Roadmap also identifies opportunities to convert CO_2 into other products, including chemicals, fuels and cement that should be pursued with federal RD&D support.

(4) INVESTMENTS IN CARBON CAPTURE WILL BENEFIT THE ENVIRONMENT, IMPROVE ENERGY SECURITY, AND PROVIDE MACROECONOMIC BENEFITS TO THE U.S. ECONOMY.

MACROECONOMIC BENEFITS

From an economic standpoint, investment in technology innovation and projects through the use of policies like the 45Q tax credits will stimulate growth in the carbon capture industry, which will create jobs and result in macro-economic benefits. CURC and ClearPath Foundation published an analysis titled "Making Carbon a Commodity: The Potential of Carbon Capture RD&D" that projects the macroeconomic benefits to the U.S. of new, lower-cost fossil energy technologies with CCUS as projected by the 2018 Roadmap.[20] 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:

- 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 Making Carbon a Commodity 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.

In addition, the new 45Q tax credit market is incentivizing investment opportunities for financial institutions as well as other types of investors. Similar trends resulted from renewable energy tax credits where a new financial market emerged for financing renewable energy projects due to the federal program. The new 45Q tax credit is causing financial institutions to evaluate investment opportunities in carbon capture projects. In the same way this resulted from the renewable tax credit market, new tools are being created for financial investors, which will improve efficiencies for project investment, act to reduce investor uncertainty and minimize perceived risks from investing in carbon capture projects.

[20] Making Carbon a Commodity: The Potential of Carbon Capture RD&D, CURC and ClearPath Foundation, July 2018, http://curc.net/making-carbon-a-commodity-the-potential-of-carbon-capture-rdd

ENERGY SECURITY BENEFITS

Innovation and investments in carbon capture for fossil fuel power generation will result in significant energy security benefits. These include:

a. producing and preserving affordable electricity for electricity consumers including increased industrial and advanced manufacturing customers, which is essential for U.S. competitiveness through a diverse generation technology portfolio;
b. improving the operational flexibility of existing and future generating plants to ensure continued electricity grid reliability and stability;
c. using captured CO_2 as a commodity to recover crude oil, thereby increasing domestic oil production; and
d. 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.

ENVIRONMENTAL BENEFITS

Investments in carbon capture will also have significant environmental benefits, including further reduction of water use and air pollutants, including nitrogen oxides (NOx), sulfur dioxide (SO2), mercury (Hg) and particulate matter (PM) (see Figures 9 and 10 below); as well as significant reductions of CO_2 emissions. The CURC-ClearPath study estimates a gigaton scale carbon capture opportunity with the potential deployment of up to 87 GW of carbon capture in the power sector.

Figure 9 - Emissions Reductions from a new Coal Unit Projected in the CURC-EPRI Roadmap

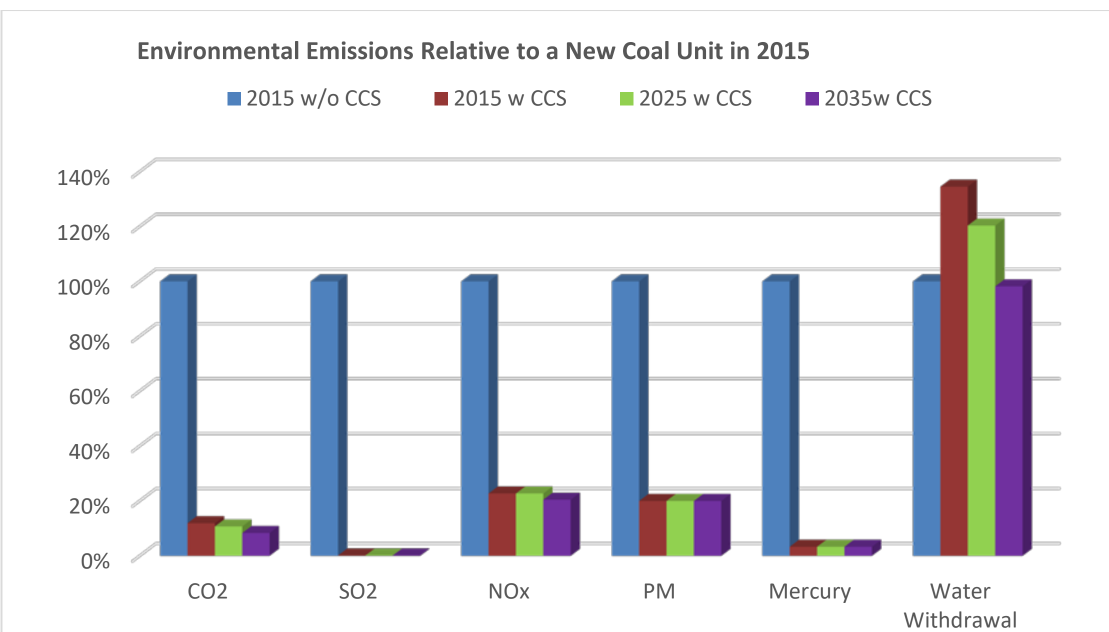
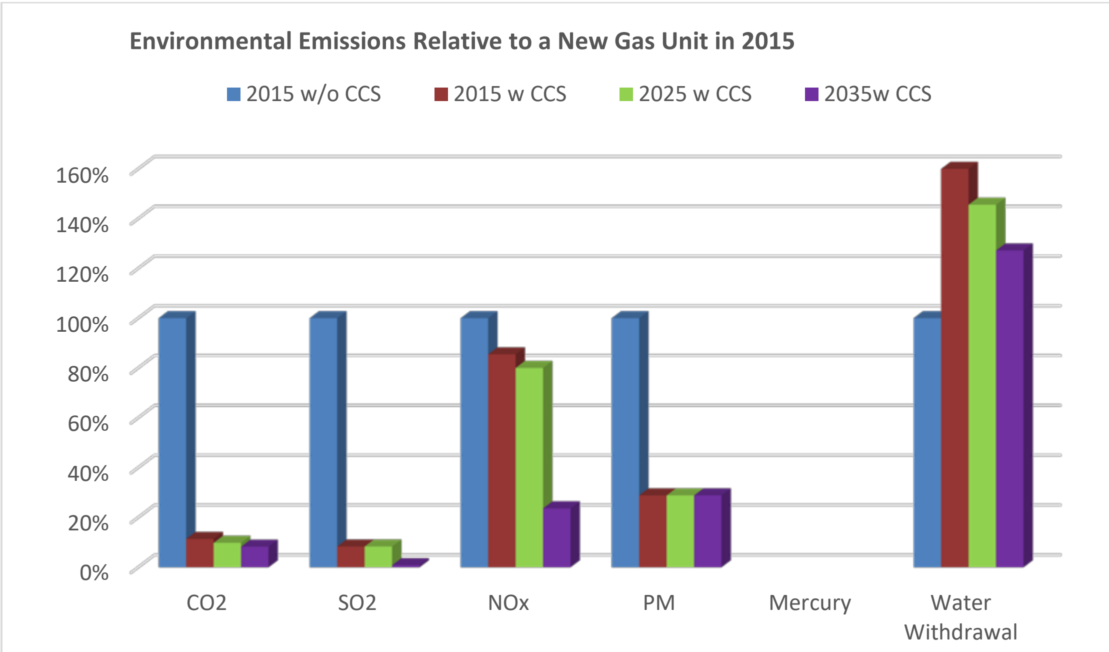


Figure 10 - Emissions Reductions from a new Gas Unit Projected in the CURC-EPRI Roadmap



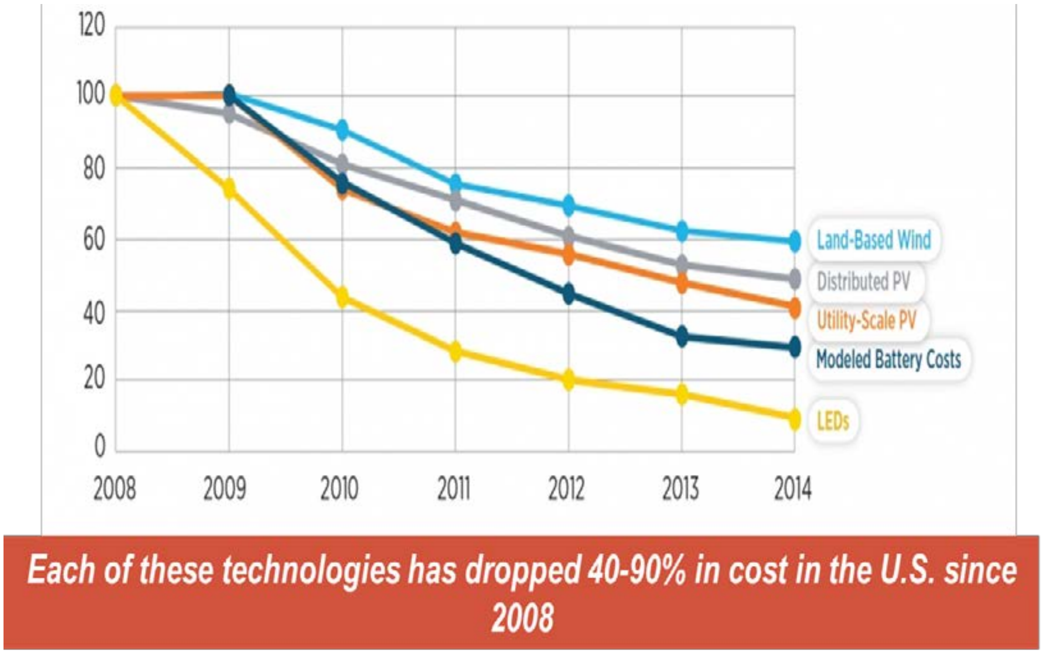
U.S. industry captures roughly 25 million metric tons of CO_2 annually using CCUS.[21] The 45Q tax credits have the potential to double or triple the amount of CO_2 captured and stored each year in the U.S. with the deployment of new carbon capture projects. The program is also incentivizing direct air capture projects which the UNIPCC has indicated will be necessary to achieve the below 2°C scenario, as well as projects that will convert CO_2 into other products and commodities, which will further reduce emissions.

(5) CARBON CAPTURE IS BIPARTISAN AND INDUSTRY AGNOSTIC. WITH ROBUST AND SUSTAINED POLICY SUPPORT, CARBON CAPTURE CAN CONTRIBUTE TO ANY DEEP DECARBONIZATION GOALS.

As carbon capture is still an emerging industry, economies of scale and best practices are not yet available that can result in efficiencies that will act to reduce the costs of implementation. If the technology innovation outlined in the 2018 Roadmap is coupled with robust and sustained deployment policies, the technology cost curve will come down and economies of scale will be achieved. In the same way the wind and solar industries were emerging as new technologies 15 years ago and not able to compete in electricity markets, fossil with CCS today cannot compete against other lower cost and subsidized forms of electricity.

[21] "Global Status of CCS", 2018, Global CCS Institute

Figure 11 - CCUS Costs Can Be Reduced with Robust and Sustained Policy Support[22]



To put this into perspective, Congress first authorized the wind production tax credits in 1992. It took 25 years of robust and sustained federal financial support for wind power to become cost competitive in electricity markets. Over the 25 year period, this amounts to roughly $23 billion in tax credits for electricity production from wind resources, not including the robust federal investments in research and development that were made or the state and regional policies that helped by requiring purchases of renewable power over that same period. While CCUS is further along in the cost and deployment curve than wind generation was even 15 years ago, it has not had the benefit of the same level or type of robust support until enactment of the 45Q tax credits in 2018.

Enactment of the 45Q carbon sequestration tax credits is one measure of the bipartisan support; a broad number of industries can implement carbon capture with the 45Q tax credits, which will be a key policy tool for catalyzing a carbon capture industry in this country. This policy will lower the cost of implementing carbon capture by providing a tax credit for every metric ton of CO_2 that is captured from industrial processes and stored in geologic reservoirs including oil reservoirs, or when the CO_2 is converted into other products like chemicals or used in cement production.

Project developers are eagerly awaiting issuance of Treasury guidance to understand how to be eligible for the tax credits in order for investments to flow into projects and meet the commence construction deadline to claim the 45Q tax credits. For the record, there are concerns that project developers are already up against the commence construction deadline, and to ensure this tax credit can be used in the way it was intended by Congress, it will be necessary to extend the deadline.

[22] U.S. Department of Energy, Office of Fossil Energy

Even as the U.S. continues to invest in the public-private partnership for research, development and demonstration of carbon capture, and in projects that will be incentivized from the 45Q tax credits, it is important to recognize that additional policy tools will help accelerate and attract investment in carbon capture projects in the same way Congress enacted several policy tools that resulted in the commercialization of other nascent energy technologies.

Several bills have been introduced that would put in place these policies and help to reduce the costs of implementing carbon capture in some industries. Some of those include:

- the "Utilizing Significant Emissions with Innovative Technologies" or "USE IT" Act (S. 383 / H.R. 1166), which would invest in carbon utilization and direct air capture research as well as streamline carbon capture and CO_2 pipeline infrastructure to help catalyze a CCUS industry;
- the "Carbon Capture Modernization Act" (S. 407 and H.R. 1796) which would modify the tax credit requirements to unlock nearly $2 billion in existing investment tax credits for carbon capture retrofits in the power sector;
- new authorizations to update the federal RD&D funding programs for carbon capture for fossil fuel power generation and for industrial capture through the "Fossil Energy Research and Development Act" (H.R. 3607) and the "Enhancing Fossil Fuel Energy Carbon Technology" or "EFFECT" Act (S. 1201); and
- two bills that would make carbon capture projects eligible for master limited partnerships (the "Financing Our Future Energy Act", (S. 1841 / H.R. 3249)), and private activity bonds (the "Carbon Capture Improvement Act", (S. 1763)) which are designed to help lower the cost of financing of carbon capture projects.

These are just some examples of the bills before Congress that have bipartisan support and that would complement the existing 45Q tax credit program. CURC welcomes the opportunity to work with this Committee in the evaluation of these policies and in the design of other policies that may be within the jurisdiction of this Committee to incentivize the development and deployment of carbon capture technology.

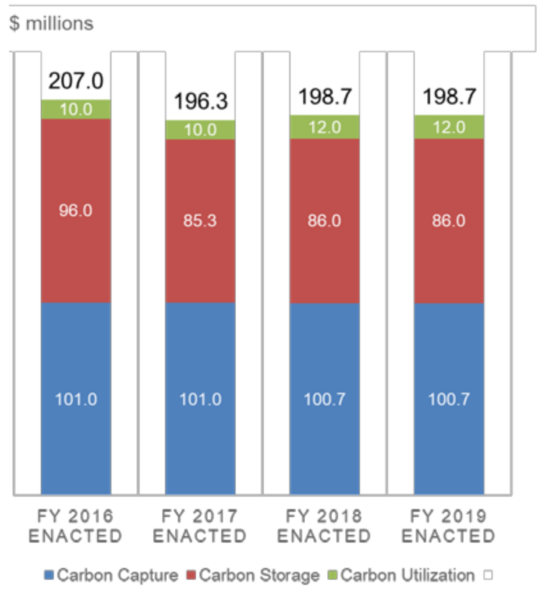
Other important policy tools for innovative research and development include federal funding for the DOE's carbon capture programs. Annually, Congress is funding the DOE carbon capture program at approximately $200 million per year (see Figure 12). The Roadmap recommends approximately double that for research, development, and testing of large scale pilot projects, with an additional $300/year over 10 years in funding for commercial demonstration projects.

Figure 12 - Department of Energy Funding for Carbon Capture and Storage Programs[23]

Carbon capture
R&D and scale-up technologies for capturing CO_2 from new and existing industrial and power-producing plants

CO_2 utilization
R&D and technologies to convert CO_2 to value-added products

Carbon storage
Safe, cost- effective, and permanent geologic storage of CO_2



In addition to these DOE programs, in FY 2017, Congress appropriated $50 million DOE to undertake a new, transformational carbon capture pilot program, and has since appropriated an additional $60 million for the program (for a total of $110 million). In FY 2019, Congress appropriated an additional $30 million to undertake Front End Engineering and Design studies, which may prove to be a more cost-effective way for DOE to advance technologies within the R&D pipeline. Congress has also continued to fund the National Carbon Capture Center in Alabama, where critical testing on both coal- and natural gas-based carbon capture systems occurs.

CONCLUSION

U.S. investment in clean energy technologies, including those for coal, has resulted in the development and deployment of technologies that are in use all over the world today. Federal investments in all forms of clean energy have been a major return on the investment for both the U.S. economy and the global environment. As the U.S. continues to invest in carbon capture, we will benefit not only from cleaner power that is necessary to meet any deep decarbonization objectives, but also from new markets for U.S. technologies both domestically and abroad. Investment in CCUS technology will transform carbon dioxide into an economic resource, lower the cost of reducing emissions, create jobs, save consumers money, and safeguard our environment and demonstrate that the technology can be used here as well as around the world – paying dividends for generations.

[23] U.S. Department of Energy, Office of Fossil Energy

THANK YOU FOR THE OPPORTUNITY TO PROVIDE THIS TESTIMONY. APPENDIX - 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 flexibility and support power systems evaluated in the Roadmap.

Transformational Advanced Energy Systems		
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: • Advanced manufacturing • Breakthrough technologies • Sensors and controls • Water management

BIOGRAPHY

Shannon Angielski

Principal, Governmental Affairs, Van Ness Feldman

Executive Director, Carbon Utilization Research Council

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.

CURC MEMBERSHIP

Power Producers
Basin Electric Power Cooperative
Duke Energy Services
LG & E and KU Services Company
Southern Company
Tri-State Generation & Transmission Association

Equipment Suppliers
General Electric
Mitsubishi Heavy Industries America, Inc. (MHIA)

Labor Unions
International Brotherhood of Boilermakers
International Brotherhood of Electrical Workers

NGOs
ClearPath Action
EnergyBlue Project

State Organizations
Southern States Energy Board
Wyoming Infrastructure Authority

Coal Producers
Arch Coal, Inc.
Cloud Peak Energy Resources LLC
Lignite Energy Council
Peabody Energy

Research Organizations
Battelle
Electric Power Research Institute (EPRI)
Gas Technology Institute
University of North Dakota Energy & Environmental Research

Technology Developers
ION Engineering
Jupiter Oxygen Corporation
NET Power

Trade Associations
American Coal Council
American Coalition for Clean Coal Electricity (ACCCE)
Edison Electric Institute (EEI)
Energy Policy Network
National Rural Electric Cooperative Association (NRECA)

Universities
Lehigh University
Ohio State University
Pennsylvania State University
Southern Illinois University
University of Illinois/PRI
University of Kentucky/CAER
University of Wyoming
West Virginia University