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Hearing to Examine the Challenges and Opportunities for Large-Scale Carbon Management

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Thank you, Chairman Murkowski, Ranking Member Manchin, and Members of the Committee. I appreciate the opportunity to be here today and am excited to share with you the transformative work being done at the Department of Energy (DOE) to advance large-scale carbon management. A lower carbon economy will not be based on a single fuel or technology. Rather, it will require an "all of the above" approach employing nuclear, renewables, fossil fuels, carbon capture and storage, and efficiency, to ensure that the United States can achieve its energy and environmental goals, while simultaneously providing economic opportunity for all Americans.

Fossil fuels, which are primarily comprised of carbon and hydrogen, supplied roughly 80% of America's energy in 2019.[1] The Office of Fossil Energy's (FE) portfolio is focused on maximizing the energy and value that can be extracted from fossil energy resources in an environmentally responsible manner. This includes: advancing the development and deployment of carbon capture, utilization, and storage (CCUS); using natural gas, coal, biomass, and organic waste to produce hydrogen with carbon-neutral or even net-negative carbon emissions; and exploring innovative ways to convert carbon dioxide (CO_2) and "carbon ore" into value-added products.

[1]U.S. Energy Information Administration, U.S. energy facts explained (May 7, 2020), *available at* https://www.eia.gov/energyexplained/us-energy-facts/

DOE is leading the world on carbon management research and development. This year, DOE's Clean Coal and Carbon Management Program is making approximately $484 million available for innovative technology research and development. With this funding DOE expects to make up to 112 awards that will support the United States' carbon management efforts.

Carbon Capture, Utilization and Storage (CCUS)

Analysis by the International Energy Agency[2] (IEA) makes it clear that fossil fuels will play a major role as an energy resource throughout this century, and that CCUS is a linchpin technology.

If governments around the world decide to adopt the goal of a low-carbon economy, or the even more ambitious net-negative carbon future, then governments and industry must be even more serious about research and development (R&D) to advance CCUS technologies. It would be false hope to bet on any single fuel solution. While this Committee has a keen interest in and knowledge of energy technologies, many people do not fully appreciate the complexities, and scale, of the U.S. and global energy system.

The United States, through DOE, is leading the world in developing emissions reduction technologies with more than $4 billion invested since 2010 in carbon capture and storage technologies. With this investment and the largest carbon capture demonstration projects in the world, the United States will be in position to deploy low-carbon technology here at home, and export much of that technology to the rest of the world.

This year alone, DOE:

- Funded five projects through our CarbonSAFE initiative totaling approximately $85 million. These projects focus on development of geologic storage sites. Each site will have the capacity to hold a minimum of 50 million metric tons of CO_2 from industrial

[2]International Energy Agency, World Energy Outlook 2019 (Nov. 2019), *available at* https://www.iea.org/reports/world-energy-outlook-2019

sources. CarbonSAFE projects will improve the understanding of site selection, and geologic characterization, permitting and monitoring strategies for commercial-scale projects.

- Plans to announce up to $46 million in awards for engineering scale testing of next generation carbon capture technologies for coal- and gas- plants, as well as engineering design studies for industrial sources; and up to $12 million for technologies that directly capture carbon dioxide from the atmosphere (often referred to as DAC technologies).

These Funding Opportunity Announcements (FOAs) are summarized in the table below.

FOA Name / Brief Description	**$ Value (anticipated or actual)**	**# Selections (anticipated or actual)**
Carbon Storage Assurance Facility Enterprise (CarbonSAFE): Site Characterization and Post-Combustion CO_2 Capture Assessment	$85,320,375	5
Crosscutting Research for Coal-Fueled Power Plants	$4,500,000	3
Novel Concepts for the Utilization of Carbon Dioxide from Utility and Industrial Sources	$15,000,000	11
Carbon Capture R&D: Engineering Scale Testing for Carbon Capture from Coal- and Natural Gas-Based Flue Gas and Initial Engineering Design for Industrial Sources	$46,000,000	10
Novel Research and Development for the Direct Capture of Carbon Dioxide from the Atmosphere	$12,000,000	9
Research for Innovative Emission Reduction Technologies Related to Coal Combustion Residuals	$4,000,000	6
Energy Storage for Fossil Power Generation	$2,900,000	16
Total	**$169,720,375**	**60**

Developing nations rely and will continue to rely upon coal and other fossil fuels to power and grow their economies. Currently, the number of coal-fueled power plants developing nations are planning and constructing is double the amount that exist today in the United States. The U.S. Energy Information Administration (EIA) projects that by 2050, 9.5 billion short tons of coal will be used around the world. That is an increase of approximately 1.4 billion short tons a year from 2019. EIA also projects that natural gas and coal will generate nearly half the electricity around the world in 2050.

It often goes unrealized that the United States is the only country with major investments in the technologies needed to reduce CO_2 emissions from the world's coal-fueled and natural gas-fueled electricity fleet and industrial sources. These investments will enable coal and natural gas power plants as well as industrial facilities to one day operate at, or near, carbon-neutral levels. DOE's Coal FIRST (Flexible, Innovative, Resilient, Small, and Transformative) Initiative is developing coal-fueled power plant designs, with carbon neutral emissions, or net negative when coal and biomass are combined as a fuel. Coal FIRST plants are also being designed with operating flexibility that allows them to support the needs of the 21st century U.S. electricity grid including facilitating the increased use of intermittent renewable electricity technologies. Some of the designs also allow the production of hydrogen. DOE is making significant progress on Coal FIRST. This year, we have:

- Completed feasibility studies (also called pre-FEED studies) for seven advanced coal fueled power plants.
- Announced $37 million for R&D to advance component technologies for Coal FIRST power plants necessary to accelerate their development.
- Announced $81 million to support advanced engineering studies (also called FEED studies) for several Coal FIRST systems, including one or more studies on hydrogen production from mixed fuels (i.e., coal, biomass, and plastic waste) that will be carbon neutral or even have net negative CO_2 emissions.

The table below summarizes the FOAs.

FOA Name / Brief Description	$ Value (anticipated or actual)	# Selections (anticipated or actual)
Critical Components for Coal FIRST Power Plants of the Future	$37,000,000	7
Design Development and System Integration Design Studies for Coal FIRST Concepts	$81,000,000	3
Extreme Environment Materials for Power Generation	$20,000,000	2
University Training and Research for Fossil Energy Applications	$5,994,000	12
Small-Scale Solid Oxide Fuel Cell Systems and Hybrid Energy Systems	$30,000,000	10
Total	**$173,994,000**	**34**

In addition to reducing emissions from coal, natural gas and industrial sources, DOE recognizes the need to address orphaned oil and gas wells to reduce methane emissions. Historically, FE partnered with the Interstate Oil and Gas Conservation Commission (IOGCC) to address orphan oil and gas wells. DOE's involvement with IOGCC and states helped craft a priority system to identify the most potentially problematic orphan wells and make sure the highest safety and environmental at-risk wells were plugged first. DOE also co-funded the first Orphan and Idle wells report from the IOGCC. Additionally, investments have been made in drone technology to identify orphan wells that may not be visible to the naked eye.

Coal to Hydrogen

DOE is working collaboratively across its program offices, including FE, the Office of Energy Efficiency and Renewable Energy (EERE), the Office of Science, and the Advanced Research Projects Agency-Energy (ARPA-E) to further reduce the cost of many technologies to produce hydrogen. FE hydrogen-related R&D programs are focused on four major areas including the development of 1) gasification and reforming technologies for low-cost, carbon-neutral hydrogen production; 2) large scale hydrogen transport infrastructure, including system requirements to utilize existing pipelines and future pipeline infrastructure; 3) large scale on-site and geological

hydrogen storage; and 4) technologies to use hydrogen for electricity generation, for production of fuels, and in manufacturing processes.

Integral to our Coal FIRST program is the ability to produce hydrogen. Hydrogen will play a significant role in a low-carbon future, because it does not emit CO_2 when converted into electricity or heat. The transportation sector is now the largest carbon emitting sector in the U.S. economy and with its mobile sources is a difficult sector in which to address emissions. Electric vehicles are part of the solution, but hydrogen-fueled vehicles are also important to transportation carbon management.

DOE is also conducting R&D on Solid Oxide Fuel Cells (SOFC) to produce hydrogen from water electrolysis. Operated in reverse, SOFCs are called Solid Oxide Electrolysis Cells (SOECs). SOECs would enable a hydrogen production source for carbon-neutral transportation, industrial fuel, and energy storage. There are also applications for reversible SOFC/SOECs that generate hydrogen for storage in off-peak electricity periods and generate electricity during peak periods. Market analyses project significant growth in near-term to mid-term hydrogen demand and SOECs show the technical potential to be a versatile, clean, and reliable source of hydrogen.

CCUS technologies can enable carbon-neutral hydrogen production from fossil fuels by capturing CO_2 from gasification or steam methane reformation. This hydrogen can be used to produce electricity and thereby reduce carbon emissions throughout the electrified portions of the economy, and when used in fuel cells can transform the transportation sector, especially heavy-duty trucks, construction equipment, locomotives, and ships.

One of the challenges to increasing the utilization of hydrogen throughout the economy is the cost of production. The United States produces over 10 million metric tons of hydrogen per year primarily used in the petrochemical and chemical industries. One of DOE's major CCUS projects in Port Arthur, Texas combines carbon capture with steam methane reforming to produce hydrogen while capturing a million tons of CO_2 a year and storing it in a depleted oil field. Since 2013, the project has captured and stored over six million tons of CO_2. On average,

producing carbon-neutral hydrogen from fossil energy with carbon capture and storage is several times less expensive than using renewable electricity to produce hydrogen.

DOE's robust CCUS R&D program has produced some impressive successes. In selected applications CCUS is technically proven. DOE is working to reduce challenges for commercializing CCUS. The most significant challenge is the cost associated with carbon capture. DOE is working to reduce this cost to $30 a metric ton by 2030 in order for the technology to be economically justified in the commercial applications.

DOE understands that fundamental changes are necessary to the operating and economic environment in which fossil energy plants function. Also of critical importance is the need for a robust financing environment that provides market certainty to support the development of CCUS supply chains, commercial infrastructure, and private sector investment as our nation's infrastructure transforms over the next 30 to 50 years.

Commercializing and deploying CCUS technologies is a realistic and necessary path to reducing CO_2 emissions on a large scale. Financial incentives will be integral for jumpstarting CCUS deployment. One such incentive is utilizing section 45Q of the Internal Revenue Service code, which provides a tax credit on a per-ton (metric) basis for projects that successfully store or utilize captured CO_2 or other qualified carbon oxides. DOE has played an integral role in providing the Department of the Treasury with the technical expertise needed to advance the implementation of 45Q tax credits.

Much like renewable technologies twenty years ago, CCUS technology, while technically viable, is not yet broadly commercially viable. More work is needed to reach full commercialization, and a critical piece of this work is incentives such as 45Q. Industry is beginning to realize the value of CCUS because tax credits like 45Q contribute to making the technology financially viable, similar to how industry viewed solar and wind power decades ago. Continued investment from government and industry will continue to drive the price down. With such incentives, the private sector will greatly accelerate the time to widespread commercialization.

Another area of our R&D program is the work we are conducting through our Carbon Utilization Program to develop technologies to transform CO_2 and carbon-based wastes into valuable products in an efficient, economical, and environmentally-friendly manner. Research and development activities address the potential opportunities and challenges associated with integrating CO_2 utilization with various power and industrial plants, such as waste heat integration, wastewater reduction, flue gas contaminant reduction, and reduced energy demand. Developing advanced catalysts, reactor systems, and processes for more efficient conversion of CO_2 to valuable chemicals will provide a viable alternative to conventional manufacturing processes.

A critical challenge across utilization technology platforms is the cost-effective and energy-efficient utilization of CO_2 to make valuable products such as building materials, chemicals, and polymers. The efficiency of reaction conversion, the amount of CO_2 stored in a product, and energy use of these utilization processes also represent critical challenges that DOE can address.

The emerging field of CO_2 utilization encompasses many possible products and applications including fuels, organic and inorganic chemicals, food and feeds, construction materials, enhanced resource recovery (e.g., oil, gas, water, and geothermal energy), energy storage, and wastewater treatment. DOE recently announced $17 million in awards to 11 projects for the utilization of CO_2 from utility and industrial sources. These technologies will utilize CO_2 as the primary feedstock to reduce emissions and create valuable products to offset the cost of capture.

Coal to Products

The National Coal Council highlighted in its "Coal in a New Carbon Age" report last year, that there are growing opportunities to utilize coal in ways that go beyond fueling power plants or steel production. These opportunities include the development of advanced materials and advanced manufacturing and can provide a strong future for coal without end-use carbon emissions. With new opportunities to utilize the carbon value of coal, rather than the heating value as in power generation, FE is developing transformational technologies to enable domestic

manufacturing of building products such carbon fiber, graphene, and carbon foam from U.S. coal that have no end-use emissions, a superior product performance, and a better lifecycle.

For example, DOE has partnered with the Ohio State University to develop building materials that are made from coal and plastic that could be used for decking and other applications. DOE is also working with CFOAM in Triadelphia, West Virginia to develop non-combustible carbon foams made from coal. These foams can be shaped and machined into virtually any configuration and have the potential to be used in a wide variety of applications including fireproof wall materials and aerospace uses.

A recent DOE market analysis concludes that a mature coal-to-products manufacturing industry could consume over 200 million tons of coal annually, employ hundreds of thousands of people, and create over a $100 billion in valuable products from coal. DOE's coal to products research and development portfolio is critical to offering coal-reliant communities an alternative market for coal that focuses on coal's carbon value instead of its heating value.

This year DOE has taken several steps to advance the technologies for coal-to-products with awards of $14 million for Advanced Coal Processing Technologies for the research and development of coal-derived products, such as building materials and infrastructure components; technologies capable of continuously producing a carbon-based rigid foam from a coal-derived feedstock; and the application, validation, and integration of several carbon-based building products into carbon-based building structures

Critical Minerals and Rare Earth Elements

DOE is exploring the opportunity to develop an economically competitive and sustainable domestic supply of critical minerals (CMs) – including rare earth elements (REEs) – from coal. REEs, and the other 34 minerals designated as critical by the Department of the Interior, are integral to the way we live – and are important for America's economic growth and national security. Currently, the United States relies almost exclusively on China as our source for CMs

and REEs. This overreliance is unacceptable. DOE is working hard to reduce this reliance and to ensure a stable supply of U.S-produced and processed CMs, including REEs.

Research indicates that coal, as a carbon ore, holds great potential for sourcing CMs and REEs domestically in the United States The United States has the largest coal deposits in the world and the National Energy Technology Laboratory (NETL) estimates that U.S. coal deposits could hold nearly 11 million metric tons of REEs, which could sustain the U.S. market for many years to come. Regionally, the estimates are nearly 5 million metric tons from Appalachia and 6 million metric tons from western state basins in Montana, Wyoming, Utah, New Mexico, Arizona, and Colorado.

DOE, in partnership with universities, national laboratories, and industry, is developing technologies to test the economic viability of extracting these valuable REEs in a sustainable manner. In June 2020, DOE announced its intent to fund $122 million to establish coal innovation centers through the new Carbon Ore, Rare Earths, and Critical Minerals (CORE-CM) Initiative. These innovation centers will focus on manufacturing value-added, carbon-based products from coal, as well as developing new methods to extract and process REEs and CMs from coal. In addition, the CORE-CM initiative will assess regional differences in resource availability and opportunities for the recovery and processing of raw materials; develop new technologies for assessment of recoverable resources onshore and offshore; and develop advanced mineral extraction technologies that maximize production of mineral feedstocks to advance U.S. industrial interests and reduce the vulnerability to foreign supply chains.

The table below summarizes the FOAs.

FOA Name / Brief Description	**$ Value (anticipated or actual)**	**# Selections (anticipated or actual)**
Carbon Ore, Rare Earths, and Critical Minerals (CORE-CM) Initiative	$122,000,000	5

Economic Improvement of Rare Earth and Critical Materials Production from Domestic Coal-Based Resources in Pilot-Scale Facilities	$4,000,000	2
Coal-Derived Carbon Materials for Building, Infrastructure, and Other Applications	$14,000,000	11
Total	**$140,000,000**	**18**

DOE's ultimate goal is to conduct R&D that enables the commercial domestic production of CMs, including REEs, from coal and coal by-products in the 2030 to 2035 timeframe. DOE's R&D into U.S.-produced CMs and REEs is an investment in America's future economic growth and our national security.

Conclusion

DOE is making progress in advancing clean energy technologies that harness all forms of energy, including oil, natural gas, coal, nuclear and renewables. From utilizing coal to making products such as decking material, roofing tiles and wall board, to transforming coal into a carbon-neutral fuel like hydrogen, to lowering the cost of CCUS, DOE's research and development into these areas is transforming the world by creating economic growth opportunities, making air cleaner, and reducing energy poverty.

COVID-19 has created a period of significant economic uncertainty across this great Nation. Despite the challenges we may face in the coming months DOE remains committed to advancing energy technologies that will change the world.

We appreciate the Committee's interest, support, and commitment to providing DOE with the tools necessary to advance the Department's mission. I look forward to answering your questions.

Thank you.