STATEMENT OF KIPP CODDINGTON, ESQ.

DIRECTOR, ENERGY POLICY & ECONOMICS

at the

SCHOOL OF ENERGY RESOURCES, UNIVERSITY OF WYOMING

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COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

UNITED STATES SENATE

concerning

"PROMOTING AMERICAN LEADERSHIP IN REDUCING AIR EMISSIONS THROUGH INNOVATION"

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Introduction

Mr. Chairman and Members of the Committee, thank you for the opportunity to appear before you today to discuss research at the University of Wyoming (UW) related to reducing air emissions through the development of new technologies and efficient practices in manufacturing and energy production and use. I am the Director of Energy Policy & Economics at the School of Energy Resources (SER) at UW, and also direct the Carbon Management Institute, which is one of SER's Centers of Excellence.

All of the projects and research areas noted in my testimony are important so that the United States remains a leader in using its abundant energy resources with reduced impacts to air quality. These air issues also are important for Wyoming, which is one of the Nation's leading energy jurisdictions. According to U.S. Energy Information Administration (EIA) data for 2015[1]:

- ✓ Wyoming produced 42% of all coal mined in the United States.
- ✓ Thirty-two (32) states received coal from Wyoming mines, with ten (10) states, including Wyoming, obtaining more than 90% of their domestic coal from Wyoming.
- ✓ Wyoming accounted for 6.2% of U.S. marketed natural gas production.
- ✓ Almost 88% of net electricity generation in Wyoming came from coal and nearly 11% came from renewable energy resources, primarily wind.

Sitting in the Rocky Mountain west, Wyoming energy resources face a variety of environmental challenges and opportunities, from the State of California's enduring air and climate regulatory programs to fuel choices by customers of Wyoming energy, whether in the State or elsewhere.

[1] Source: "Wyoming, State Profile and Energy Estimates" (EIA, updated December 15, 2016) (available at https://www.eia.gov/state/?sid=WY).

Testimony

My testimony provides a very broad overview of UW's research, divided into the following topical areas: (1) first, reducing atmospheric emissions of greenhouses (GHGs) and criteria constituents associated with the combustion and/or production of fossil fuels; (2) second, managing, capturing and utilizing carbon dioxide (CO_2) atmospheric emissions from the combustion of fossil fuels; and (3) third, understanding the decomposition behavior of coal and how coal molecules can be deliberately reconfigured to make valuable carbon-rich products which support other industries, including chemicals, building construction, agriculture and energy storage. I conclude with some brief remarks about our policy work and ongoing engagements with regional stakeholders in the western Rocky Mountain and Great Plains regions.

Topic Area #1: Reducing Anthropogenic Emissions

UW has several research programs underway related to the development of novel technologies to reduce atmospheric emissions of anthropogenic GHGs and criteria constituents, including the following:

- ✓ Flameless Pressurized Oxy-Fuel Combustion

This technology, which involves the combustion of coal at elevated pressure in a highly preheated stream of oxygen that is diluted with both CO_2 and water, has the goal of:
(1) recovering energy from low-rank coal and other brown fuels; (2) enabling CO_2 recovery on an economically viable basis; and (3) minimizing emissions of nitrous oxides, particulates and heavy metals.

- ✓ Co-Firing Coal With Biomass

UW conducts extensive research on co-utilization of biomass with coal for reduced emissions in combustion, gasification and pyrolysis. Our research focuses on near-term substitution in existing power plants, as well as long-term advanced conversion technologies.

- ✓ Biomass for Sustainable Food, Energy and Water Resource Development

UW research focuses on novel bio-resource materials for sustainable food, energy and water resource development. Research tasks here include: (1) production of fuels and biochar from biomass materials; (2) enhancement of biochar quality through photochemical and ultrasonic chemistry and functionalization; and (3) application of functionalized and photochemical and ultrasonic chemistry-enhanced biochar for CO_2 capture, water treatment and food production.

- ✓ Measurements of Methane and Volatile Organic Compound (VOCs) Emissions from Oil & Gas Operations

Flux estimates of methane and VOCs made by the UW Center for Air Quality, while technically challenging, are essential for operators to understand what their true emissions are and how close they are to inventory estimates. Utilizing flux measurements to improve inventories is essential in developing functional photo-chemical models that can replicate the impacts of oil & gas operations on air quality, especially wintertime ozone. Having functional models is a critical way that operators can make good decisions about the most effective and economical ways to minimize air quality impacts from the expansion of energy production.

And we are pushing the science in terms of directly measuring VOC fluxes. UW is one of only a handful of institutions of higher education in the United States that flies its own aircraft for atmospheric research.

On a related front, the Casper-based Enhanced Oil Recovery Institute assists Wyoming operators with the engineering and sourcing of new technologies that facilitate economic reductions in methane emissions.

Topic Area #2: Capturing and Utilizing Atmospheric Emissions of CO_2

The State of Wyoming is an ideal jurisdiction to advance research and projects related to capturing and utilizing emissions of CO_2. For example, led by the Wyoming Infrastructure Authority and with the support of many private- and public-sector entities in Wyoming, the Gillette-based Integrated Test Center (ITC) will soon serve as an operational test site for CO_2 capture technology developers and providers to evaluate carbon capture utilization and storage (CCUS) technologies using actual coal-based fuel gas equivalent to a 20 MW generation load. The ITC is also hosting the coal-track of the $20M NRG COSIA Carbon XPRIZE, a global competition to develop breakthrough technologies that convert CO_2 emissions from fossil-fuel combustion into products with the highest net value, such as enhanced concrete, biofuels, nanotubes and fertilizers. Wyoming is one of a handful of states with existing CO_2 pipeline infrastructure, with ongoing efforts to expand the same under the Wyoming Pipeline Corridor Initiative. Wyoming also has an existing CO_2-enhanced oil recovery (CO_2-EOR) industry and has enacted laws to encourage the environmentally responsible siting and operation of CCUS-related projects in the State.

UW has several research programs underway in this field, too, including the following:

- ✓ U.S. Department of Energy's DOE's Carbon Storage Assurance and Facility Enterprise (CarbonSAFE) Program

Relying upon interdisciplinary public- and private-sector teams with expertise in commercial project development, non-EOR geologic storage (e.g., saline formations), CO_2-EOR, law and

project finance, we are advancing two project sites in Wyoming under Phase I of DOE's CarbonSAFE program, a federally supported endeavor to hopefully site one or more large-scale integrated CCUS facilities throughout the United States by the 2025 time frame. We are honored to be working with our utility partners in these endeavors, both of whom continue to do yeoman's work to advance CCUS: (1) PacifiCorp/Rocky Mountain Power; and (2) Basin Electric Power Cooperative. These efforts build upon UW's prior CCUS work under the Wyoming Carbon Underground Storage Project, a pioneering three-year research project that characterized two potential CO_2 storage reservoirs (the Weber Sandstone and Madison Limestone) on the Rock Springs Uplift in the southwestern corner of the State.

- ✓ U.S.-China Clean Energy Research Center (CERC)

In conjunction with colleagues at West Virginia University, University of Kentucky and elsewhere, UW is pleased to play an integral role in DOE's CERC program. CERC is a multi-year DOE effort to foster collaborative research and development of CCUS and clean coal technologies between the U.S. and China.

- ✓ CO_2 Capture Technologies

UW researchers continue to advance a variety of CO_2 capture technologies including the novel use of catalysts that augments conventional gasification and chemical looping solutions.

- ✓ CCUS-Based Biofuels

In collaboration with colleagues at Montana State University, the University of South Dakota and elsewhere, UW is part of the recently announced four-year National Science Foundation initiative to determine if changes in commodity production and capturing CO_2 are sustainable, or even feasible, in the Upper Missouri River Basin.

Topic Area #3: Advancing Applied Research Related to Non-Btu Markets for Coal and Coal By-Products

UW is alone in developing and advancing novel and innovative technologies related to the extraction and production of valuable non-Btu products from coal. The primary focus of this research is to advance coal utilization as a feedstock to manufacture and generate valuable non-Btu coal-related products, such as carbon fiber and carbon-rich chemicals, agricultural and building products. The manufacture of some of these coal-based products has the potential to be deployed as a pre-treatment before coal is combusted to offset the typically high costs associated with post-combustion carbon capture solutions. And some of these products – e.g., graphite and carbon fiber -- are predicted to be in short supply as the demand for lightweight materials, renewable energy and the like grows in the years ahead.

Our work on Rare Earth Elements (REE's) is also expanding. UW researchers – in collaboration with colleagues on campus and throughout the region – are separately investigating the identification, characterization and separation of REE's from coal, coal by-products and produced waters. Expansion of domestic sources of REE's remains a high priority for policymakers.

Some Closing Remarks about UW's Energy Policy Work and Regional Collaborations

UW's innovative work extends beyond the lab bench to the policy realm. Most recently, UW: (1) played a leading role in the 2016 report by the National Coal Council regarding geologic and non-geologic technologies that hold promise to utilize CO_2 as a feedstock for products; and (2) published an interdisciplinary analysis of the impact of the social cost of carbon in the development of energy projects on federal lands.

A brief note about regional collaborations: Over the years and continuing, UW researchers in these and related areas have benefited from a variety of regional relationships, from Idaho National Laboratory (INL), including the Center for Advanced Energy Studies, to the Energy & Environmental Research Center at the University of North Dakota.

Conclusion

This concludes my testimony. I commend the Committee for addressing the issue of the role that innovative technologies are playing in reducing air emissions. UW is doing its best to advance the frontiers of these research areas for the benefit of a variety of stakeholders. The ongoing federal role in supporting these research endeavors is imperative. Mr. Chairman and Members of the Committee, I would be pleased to answer any questions that you may have.