Written Testimony of Brian J. Anderson to the Clean Air and Nuclear Safety Subcommittee
July 25, 2017

Chair Capito, Ranking Member Whitehouse and members of the Subcommittee, thank you for the opportunity to offer relevant testimony and to answer your questions in my areas of experience and expertise.

I am the Director of the WVU Energy Institute at West Virginia University in Morgantown, West Virginia. The WVU Energy Institute is the central organization on the West Virginia University campus with a mission to coordinate cross- and multi-disciplinary research across our 14 schools and colleges in energy as well as working with the state of West Virginia to stimulate economic development while utilizing our energy resources responsibly. In addition to my role as director, I am the GE Plastics Materials Engineering Professor of Chemical Engineering and have 17 years of energy research experience primarily in chemical engineering and in subsurface science as related to CO_2 sequestration, natural gas hydrates, unconventional gas production, and geothermal energy.

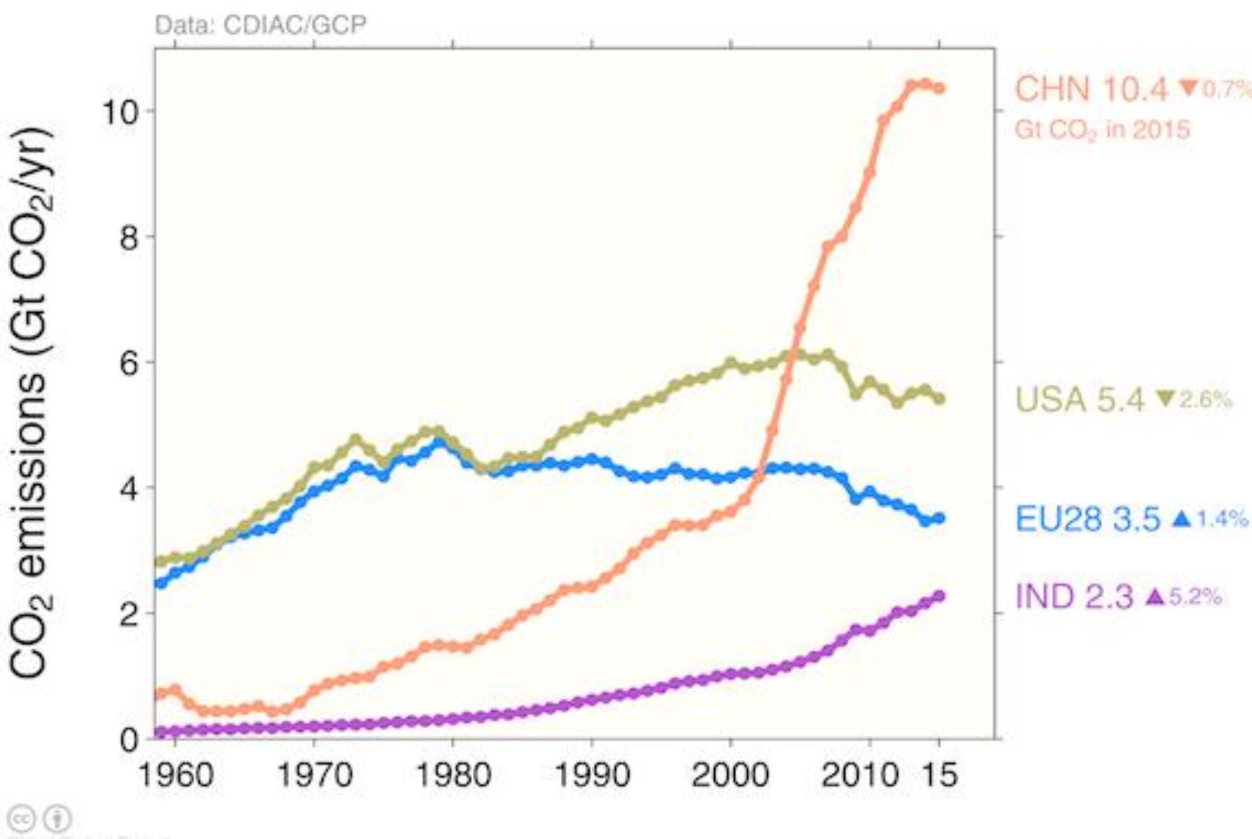
West Virginia University is a public, land-grant, research-intensive university founded in 1867. It is designated an "R1" Research University (Very High Research Activity) by the Carnegie Foundation for the Advancement of Teaching; funding for sponsored research programs exceeds $170 million. The Morgantown campus houses the West Virginia University Energy Institute, the National Research Center for Coal and Energy, and the Center for Alternative Fuels, Engines and Emissions which discovered the Volkswagen diesel engine emissions software installation that allowed its diesel engines, in test mode, to meet emissions compliance standards, but to operate out of compliance when not in test mode.

The university has active and ongoing research related to operating improvements on existing coal-fired power generation, the recovery of rare earth elements from coal wastes, instrumentation and sensor development to accurately measure fugitive emissions from shale gas wells, analysis of sub-surface geological structures and their applicability to store gas liquids, store carbon or produce gas. The university also has developed sophisticated software and algorithms that can model complex fossil fuel combustion systems, as well as complex electric transmission grids responding to variable generation from intermittent sources like solar and wind.

Additionally, the U.S.-China Clean Energy Research Center Advanced Coal Technology Consortium is based in the WVU Energy Institute at West Virginia University in Morgantown, West Virginia. The consortium is one of five consortia that were created through a bi-lateral Protocol signed in 2009 between the United States Department of Energy and two agencies of the People's Republic of China: the Ministry of Science and Technology and the National Energy Administration. The initial phase of Center's Protocol spanned five years (2011-2015) and in 2015 was extended an additional five years (2016-2020) under the direction of Jim Wood. From 2009 to 2012, Jim was the Deputy Assistant Secretary for what is now called the Office of Clean Coal and Carbon Management in the U.S. Department of Energy's Office of Fossil Energy. He was responsible for the agency's coal research program and the large demonstration projects co-funded with industry under the third round of the Clean Coal Power Initiative, including funds added from the American Recovery and Reinvestment Act of 2009.

The United States is blessed with an abundance of diverse electric generation sources. Diverse sources of generation improve transmission grid operation, moderate retail electricity costs, and reduce unhealthy emissions levels. The benefits of diversity are not unlike the mitigation of risk from diversity in savings and investment portfolios. Research into carbon emissions reduction is an important strategy to preserve the diversification of generation enjoyed by the United States. Although both the rate of carbon emissions growth, and its emissions in absolute numbers have begun to decline, much of this is due to substitution of lower carbon emitting generation for coal-based generation. Part of this also is due to the reduced growth of GDP over the last decade and one could expect this decline to slow, and possibly reverse, when U.S. GDP growth rates increase. Having economic and commercial technologies to capture, reuse or permanently store carbon before its emissions are atmospheric, should be part of strategies to maintain the diversification of generation, and indeed provide economic benefits when these technologies are exported.

Many parts of the world are not equally blessed with diverse generation, and to a larger extent must rely on inexpensive local fuel sources high in carbon and resulting carbon emissions. Among these are the two most populous countries in the world, China and India. In the 2000 World Energy Outlook, the International Energy Agency estimated China's emissions would be 18% of the global total in 2020. In 2015 the actual value was 29%. Recently Chinese President Xi Jinping announced China's carbon emissions would peak in 2030.



West Virginia University's research activities help support diverse, low-carbon generation in many ways:

1. Models of complex combustion systems that burn fossil fuels in pure oxygen in order to explore the thermodynamic properties of flame development, which is a precursor to designing pilot and demonstration combustors with carbon capture and efficient heat transfer properties;
2. Models of complex combustion systems that burn fossil fuels in vessels containing inexpensive oxidants, like iron oxide, or aluminum oxide, that can be used to develop technical solutions for combustion without air, which may generate pure dense phase CO_2, ready to transport to a storage repository, or for reuse;
3. Models of complex electric transmission systems that must maintain voltage, frequency and capacitance stability when multiple sources of diverse generation are competing to supply a demand curve that does not match the intermittent properties of the diverse sources of generation;
4. Down-well sensors and technologies, including innovative fiber optic and micro seismic sensors, that better describe formation performance during formation stimulation and drilling, including gas production flow paths and flow paths of stimulation fluids and proppants that improve safety and well bore efficiency;
5. Above-well sensors that detect even small releases of greenhouse gasses during stimulation, drilling or production operations of shale gas wells;
6. Chemical reaction research that improves gas and gas liquids conversion processes, improves efficiency, and reduces fugitive emissions;
7. Rare earth element extraction processes and strategies from U.S. coal mine wastes, and potentially combustion ash, that are critically important for U.S. defense and industrial uses and that are found now in, and often controlled by, other countries;
8. Analysis and measurement of pipeline fugitive emissions, and control strategies that minimize those emissions;
9. Research into technical and economic advances of renewable geothermal sources of energy;
10. WVU also is leading a tri state (WV, PA, OH) effort to undertake rigorous sub-surface analyses of proposed Appalachian Storage Hub locations for gas liquids that will greatly reduce fugitive emissions of shale gas produced in Appalachia as compared to emissions released if that gas was transported to hubs south or east of Appalachia.

West Virginia University's role in managing the U.S.-China Clean Energy Research Center Advanced Coal Technology Consortium gives the university good visibility into China's research and development on solutions to carbon emissions. Consortium members include the University of Wyoming, the University of Kentucky, Washington University (St. Louis), National Energy Technology Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, the World Resources Institute, Alstom (now GE) Power, Arch Coal, Duke Energy, the Electric Power Research Institute, the Gas Technologies Institute, Jupiter Oxygen Corporation, LP Amina LLC, Peabody Energy, the Southern Company, and Stock Equipment Company. Research undertaken by the consortium includes advanced combustion technologies, including chemical looping and pressurized oxy-combustion of coal, pre- and post-combustion carbon capture technologies and techniques, including micro-algae absorption of CO_2, and advances in carbon conversion technologies.

In the seven years subsequent to the Protocol signing ceremony, a number of important relationships have developed between U.S. and China consortium members. West Virginia University has ongoing collaborations with the Shenhua Group Ltd. (the largest coal producer in the world), and Shaanxi Yanchang

Petroleum Company Ltd. There is evidence through these, as well as other business and academic relationships that China depends on coal for approximately 85% of its energy needs. About 50% of its coal consumption is used in the generation of electricity. The balance is used to derive chemicals, and liquid fuels from coal. China's dependence on coal should not be underestimated, nor should effects of the lack of generation diversity on its transmission grid. Consequently, China has made large commitments and investments into cleaner utilization of coal and particularly criteria and climate change emissions reductions. The chart below compares China's current regulations for criteria emissions with those of the U.S. and EU. The *, **, *** notations refer to location- relevant (usually Provincial) limits now overridden by the lower National Limits:

TABLE 1

Coal-fired power emission standards in China, the United States, and the European Union

Conventional air pollution standards for new and existing power plants, in milligrams per cubic meter (mg/m3)

		China	United States	European Union
Nitrogen oxide	Existing	100*	135	200
	New	50	95	150
Sulfur oxide	Existing	50/100/200**	185	200
	New	35	136	150
Particulate matter	Existing	20/30***	19	20
	New	10	12	10

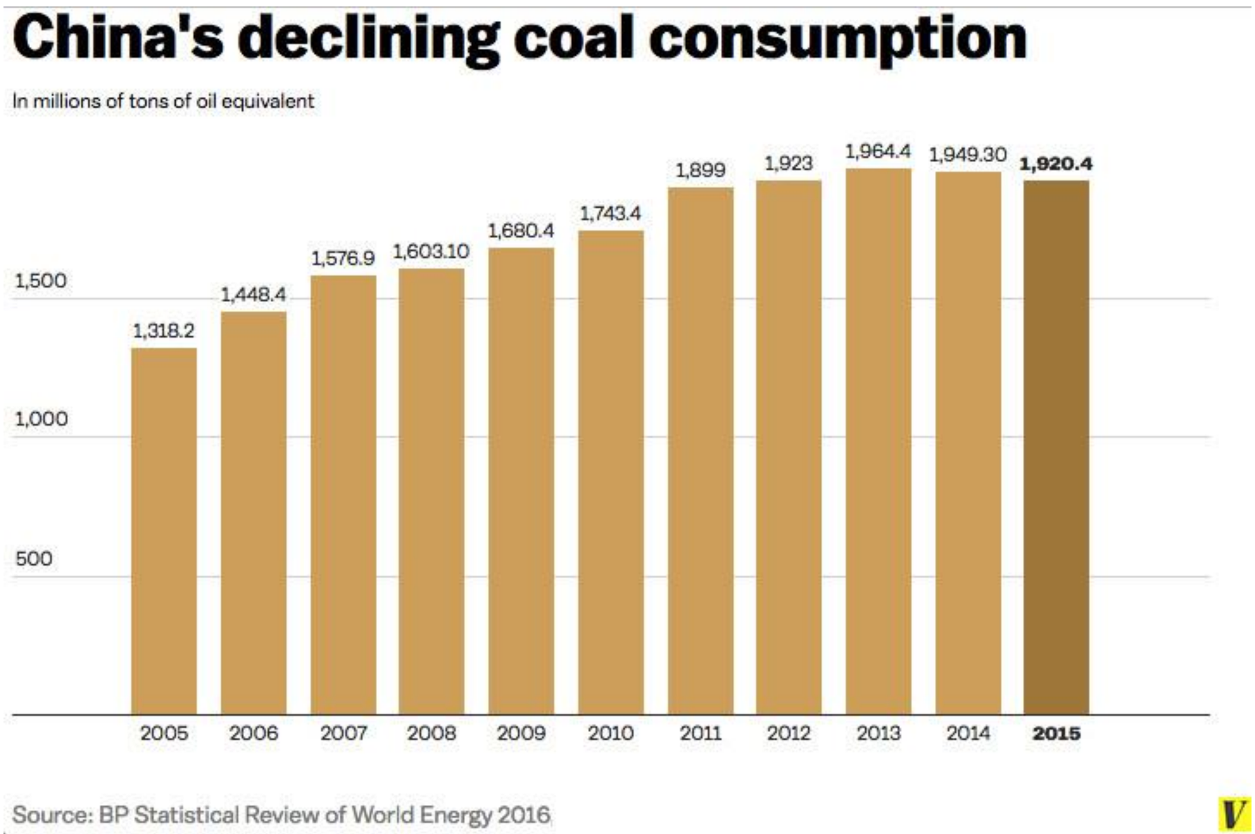
https://www.vox.com/energy-and-environment/2017/5/15/15634538/china-coal-cleaner

https://www.americanprogress.org/issues/green/reports/2017/05/15/432141/everything-think-know-coal-china-wrong/

China is an observant partner; it studies decisions other countries have made, and the consequences, of those decisions. It appears that China's principal choice to reduce emissions from coal-fired electrical generation is efficiency increases to its coal-fired fleet. China's most efficient coal-fired plant is the 1000 MW Guodian Taizhou plant which operates at about 45% thermal efficiency (http://www.powermag.com/who-has-the-worlds-most-efficient-coal-power-plant-fleet/).

By comparison, the most efficient coal-fired plant in the U.S. is the privately-owned Longview Power LLC which operates at about 40% thermal efficiency. There is evidence that China's consumption of coal is declining. Some attribute this to an increase in renewable energy. While China is installing as much renewable energy as possible, it also has 36 nuclear power plants in operation, 21 under construction and plans to have 150 Gw, or approximately ten percent of its electric generation, in operation by 2030 (**http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx**).

China also is decommissioning its old, low efficiency coal fleet and replacing it with high efficiency, low emissions power fueled with indigenous coal. For every megawatt of old coal capacity China replaces with new coal capacity, its criteria and carbon emissions decline 10% on a per unit of electricity generation basis. So does its coal consumption.



The low generation costs from renewable and gas-based electricity are putting pressure on the U.S. coal-fired base-load fleet principally because it operates, on average, at 32% thermal efficiency. Most of the operating capacity has been retrofit with criteria emissions controls, and is well-maintained. However, because these units are called into service later in the daily dispatch cycle, they often operate below full load, and undergo frequent pressure and temperature cycles that were not accounted for in those plant designs when they were constructed. Operation at reduced load also reduces a plant's thermal efficiency, which increases its carbon footprint.

Since 2011, roughly 350 coal-fired generating units have shut down according to the Energy Information Agency (https://www.wsj.com/articles/coals-decline-spreads-far-beyond-appalachia-1497870003).

When an owner determines a plant is no longer viable it is mothballed, and ceases to be maintained. The rotating equipment, electrical and controls systems decay rapidly. A similar issue faces the U.S. nuclear fleet which is not a carbon emitter. In both cases diversity of generation is reduced, investors or customers have expensive stranded assets to deal with, jobs are lost, and local property tax revenues decline, often with serious economic consequences to host communities.

There may be gigawatts of operating coal-fired generation that under some circumstances could be upgraded with technologies that would improve operating efficiency and reduce emissions, thereby allowing those units to compete for more operating hours and minimize the effects of cyclic operation. Some of these technologies could include conversion from coal to natural gas, replacing old turbine blades, condenser and feedwater heater upgrades, and control system upgrades. Interest from electric generators in efficiency improvements could benefit research centers and U.S. vendors that have largely exited this sector, or moved operations to Asia. To the extent these units then continue to operate economically, local host communities will continue to enjoy economic benefits associated with jobs and property taxes.

West Virginia University is committed to maintaining active, outcomes-based research that will improve the carbon footprint of the resources available in the Appalachian Basin so that industry and commerce may continue to grow and provide opportunities to its citizens. The university also is committed to maintaining robust business and academic relationships with partners in Europe, and Asia. Trans-global collaborations like these accelerate the development of electric generation technologies that improve safety, improve maintenance and operating efficiencies, and promote adoption of technologies that control emissions and improve air quality. This helps regional economic expansion, promotes low cost electric generation from diverse sources, and improves transmission grid stability.

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