WEST VIRGINIA UNIVERSITY ENERGY INSTITUTE:

"ACCELERATING I.P. COMMERCIALIZATION OF CLEAN ENERGY SOLUTIONS"

ACADEMIC MEDIA DAY; APRIL 1, 2019

Appreciate the opportunity to speak for a few minutes at this year's Academic Media Day, and will be happy to take questions in the session provided later.

We have spent some time recently, looking over the structure of the Energy Institute particularly with regard to integrating the team at the National Research Center for Coal and Energy into the Energy Institute. We expect this to be completed in May, and certainly before the start of WVU's 2020 fiscal year.

At that point, the Energy Institute will focus on a number of research programs related to Clean Energy.

In the world of research, advances in technology are usually identified according to technology readiness level, or TRL. The customary scale is from 1 to 9 with 1 identified as Basic Research Technology, or perhaps an unproven concept lacking any testing, and 9 identified as full commercial application. The terminology varies somewhat depending on the organization: for example NASA's TRL definitions differ from the European Union, but each use a 1-9 scale. In most nomenclatures, TRL 5 means a large scale prototype (or pilot) tested in its intended environment.

There is an interesting term used in both the private and public sectors to describe the movement of technology along the path from TRL 1 to TRL 9. That term is called "the valley of death" and reflects the idea that the transition from TRL 1 to TRL 9 is anything but an easy transition. It

also metaphorically identifies the gap between research-based institutions and commercial applications in the marketplace. Sometimes the gap is created by financial pressures, sometimes a great innovation is found to be non-scalable, sometimes it's a matter of market acceptance, or the lack of ability to manufacture the technology at a reasonable cost.

Between 2005 and 2014, eight large multi-million dollar demonstration projects were funded by Congress. Such funding requires the project sponsor to co-fund the project at an 80%-20% split. The purpose of that program was to demonstrate a range of technologies for carbon capture; each project would have been considered at TRL 5. Only two projects made it into commercial operation; the other six either were unable to achieve commercial financing, or unable to reach commercial

agreements between vendors and contractors, so failed. The two successful projects now in operation are Petra Nova, in Houston, and Archer Daniels Midland in Decatur, Il. Petra Nova is capturing about 1.6 MM TPY of CO_2 from a 240 MW flue gas slip stream at a coal-fired power plant; ADM is capturing about 1 million tons per year of CO_2 from an ethanol distillation process. That carbon is injected into the Mount Simon saline aquifer; the Petra Nova carbon is injected into a nearby oil field--- and increased oil production from about 300 bbl/yr to about 15,000 bbl/yr. Interestingly, the technology (and substantial funding) in the Petra Nova project is Japanese; the technology in the ADM project is German. Importantly, even when the technology in six projects was de-risked by 80% with public funding, private sector sponsors were not able to bring the projects to fruition.

The Energy Institute supports research in resource extraction, such as innovative techniques for the injection of carbon dioxide to produce oil from low pressure formations. It's estimated there is still 50% of the original oil remaining in most formations that have lost pressure. Carbon dioxide is highly miscible with most oils, and re-pressurizing formations is done in ways that result in much of the carbon dioxide remaining captured by the formation. It is generally thought that producing oil using this technique produces less carbon emissions than producing oil by drilling a new well. This is called Tertiary Oil Recovery, or Enhanced Oil Recovery and the Energy Institute is engaged in research activities to increase the amount of residual oil that can be produced using this technique. Today, the **only** commercially viable capture systems for

coal-fired power plants are those that use enhanced oil recovery as a means of offsetting the capital costs and operating expenses.

For several years, the Energy Institute has been a partner in a program that studies the reaction of underground formations to induced fracturing and stimulation. This research has produced results that suggest the amount of natural gas leakage from a well pad can be reduced to near zero, and that most of the air borne particle emissions are the result of vehicles moving to and from the well pad. Additionally knowing the shale formation's subsurface geology and properties with fidelity has allowed researchers to create algorithms that can efficiently, and effectively produce natural gas and can identify locations along laterals that are suitable for fracking stimulations, and other locations that are not. This can enhance the production of a given lateral, but

more important, the number of failed fracks is reduced, also reducing the above ground air borne emissions- which makes producing natural gas cleaner. It also reduces the cost of producing and accelerates the transition to electric generation using natural gas. Natural gas has about 57% the amount of carbon compared to coal. However, due to the higher efficiency of gas-fired electric power plant compared to coal, the carbon emissions are only 45% those of a coal fired plant. That means replacing a typical 600 MW coal-fired generator with a 600 MW natural gas generator would produce the same amount of electricity with 2.2 MM TPY less carbon emissions.

Electrical load growth has been flat for a number of years. Even so, the shift away from coal to natural gas, and renewable energy has produced a significant decline in U.S. CO_2 emissions.

Notwithstanding the ongoing trade negotiations between China and the United States, the Energy Institute manages many of the education and training agreements that are part of the WVU and Chinese relationship. This includes managing the U. S.- China Advanced Coal Technology Consortium, a government-to-government multi-university, and private sector research program developing carbon capture technologies as diverse as algae absorption of CO_2 with the production of valuable chemicals from unique algae species grown in super saturated CO_2 atmospheres --- to more efficient coal combustion technologies with carbon capture. The consortium agreements include an effective means of protecting and sharing the parties' intellectual property.

The Energy Institute also collaborates with WVU's CIGRU, the Center for Innovation in Gas Research and Utilization on its important research into

separating natural gas into its components. Currently, industry does this through a process called steam--methane reforming, which is a process that produces large amounts of carbon dioxide. EPA estimated the manufacture of hydrogen in 2015 produced 25 MM metric tons of CO_2. CIGRU is developing a low-temperature microwave and catalyst process to create the same outcome but without producing carbon dioxide.

Additionally, there is a renewed focus on the National Alternative Fuels Training Consortium, the purpose of which is to educate automotive technicians, first responders, and the general public on the importance of electric vehicles, natural gas, ethanol and biodiesel fuels, and the proper maintenance and repair procedures of those vehicles. Among other benefits, is the acceleration of these technologies into general commerce, displacing gasoline and diesel powered vehicles.

In addition to its large natural gas resources, this county in West Virginia sits over a large thermal dome below the Marcellus and Utica shales. **How do we know this**? It was validated with data observed during the testing performed in conjunction with subsurface reactions to fracking and stimulation. Currently, the Energy Institute is collaborating on characterization of this dome. If this work yields good results, the dome could be used for steam to create hot water, and heat as much of the campus as possible. If the results are excellent, the small power plant down town could be retired and replaced by geothermal energy from the dome.

The West Virginia Water Research Institute also is part of the Energy Institute. Its work on mine reclamation, water management treatment

and recovery in oil and gas, and rare earths have been well-covered by the media.

The previously mentioned “Valley of Death” metaphor leads many investors to focus on areas of particular interest, with higher commercialization potential, and with more tolerable risk profiles. For a number of years, the Energy Institute has supported a program called TransTech, which involves producing a local conference that features numbers of entrepreneurs who pitch their technologies to a panel of venture capitalists and angel investors. Each pitch is evaluated by the panel and by the end of the conference an entrepreneur is selected and awarded a cash prize. There are a number of similar conferences around the country. Attendance by panelists and entrepreneurs is by invitation; often acceptance depends on how big an award is made. The Energy

Institute sees this program as an important responsibility, especially to drive commercialization of energy technologies, because West Virginia is not populated with as many large investor funds compared to Silicon Valley, New York, and Boston. By supporting a TransTech conference locally, once or twice per year the intention is to create events where launching a new product does not drive entrepreneurs to seek funding elsewhere, where that "elsewhere" usually will reap the benefits.

Partly from observing the failure rate of the federal large demonstration program, WVU stood up the Energy Institute as a means of providing support for research projects showing early economic potential. The tilt in the project portfolio is toward projects with environmental benefits. It is not a quick fix portfolio, or a one idea will solve the problem

portfolio. It is more geared to help guide outcomes-based research that has commercial potential and can be commercialized in West Virginia for the benefit of West Virginia's citizens.

Thank you for your attention.