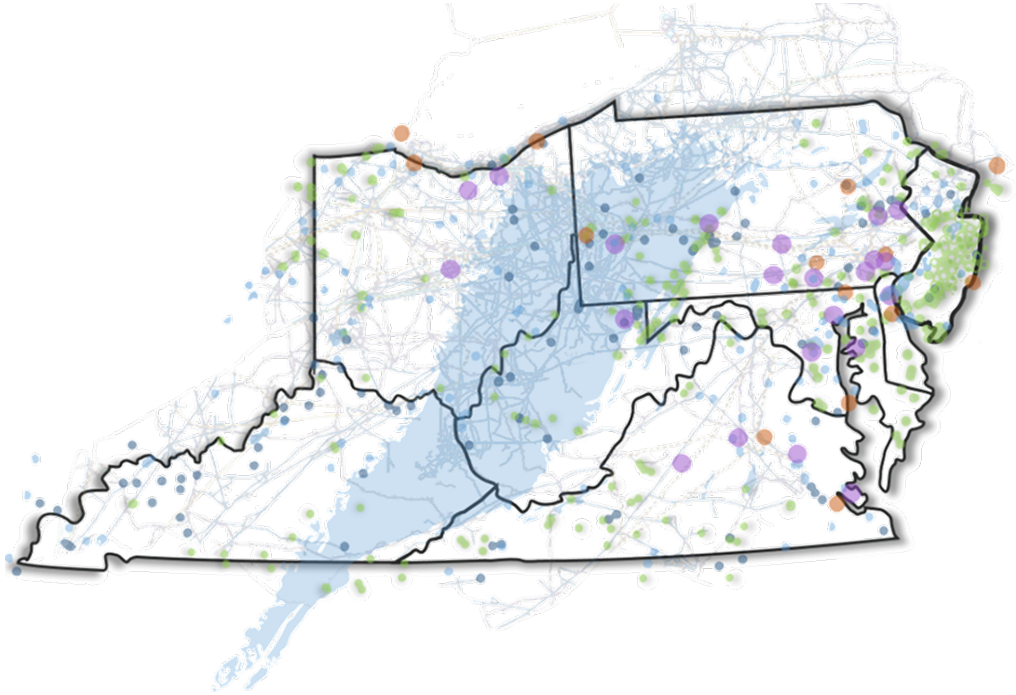
West Virginia University

Mid-Atlantic Region Energy Innovation Forum Report

Morgantown, West Virginia • September 12, 2016

WEST VIRGINIA UNIVERSITY

MID-ATLANTIC REGION
ENERGY INNOVATION FORUM REPORT



Hosted by the the WVU Energy Institute at West Virginia University

September 12, 2016

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EXECUTIVE SUMMARY

The Mid-Atlantic Region, consisting of the eight states, KY, OH, PA, WV, MD, VA, DE, NJ, plus DC, is blessed with abundant resources including oil, coal, and natural gas, and it is vital that these resources remain a part of the clean energy dialogue as our nation moves toward a new energy future. The region is also home to a diverse array of highly influential government and private research facilities and academic institutions, making it an epicenter of and a driving force for energy research.

On September 12, 2016, the Energy Institute at West Virginia University hosted the Mid-Atlantic Region Energy Innovation Forum. This Regional Innovation Forum was co-organized by West Virginia University and the National Energy Technology Laboratory with assistance from KeyLogic Systems, Inc. The goal of the forum was to discuss the energy innovation ecosystem in the Mid-Atlantic region and share ideas for creating pathways to a cleaner energy future.

The Mid-Atlantic Region's diverse population of 55 million people, and its robust energy resource base makes it unique. The western half of the region is blessed with abundant fossil energy resources, particularly coal and natural gas, while the eastern half of the region hosts the majority of the population. At the forum, engaged representatives from 7 of the 8 states in the region participated from all sectors of the energy ecosystem: academia, industry, national laboratories, government (federal, state, and local), and non-governmental organizations.

The forum featured keynote talks by U.S. Energy Secretary Ernest Moniz, U.S. Senator Joe Manchin, and Congressman David McKinley, as well as a discussion by state representatives on the Tri-State Governor's Energy Agreement between West Virginia, Pennsylvania, and Ohio. These talks featured the mechanisms by which the region has begun to coalesce into natural partnerships and consortia to try to tackle some of the most challenging issues in the energy sector across the region.

A panel specifically focused on Regional Challenges and Opportunities highlighted the need for innovation within the economies of the Mid-Atlantic Region that have historically been based heavily on fossil energy resources. It is through partnerships and collaboration that innovations across the energy innovation ecosystem will be uncovered.

Topical panels were held on:

- Innovation opportunities for fossil fuels in a future low carbon economy
- Innovation opportunities in other clean energy technologies
- Policies Facilitating Sustainable Clean Energy Development
- Regional Innovation Investment and Commercialization

In each of these panels, discussions were focused on innovations and partnerships and five priority innovation focus areas emerged:

- **Clean fossil**: advanced power cycles, fuel cells, CCUS, and increased natural gas utilization
    - NETL, Industry partners (i.e. B&W, ExxonMobil, Siluria, Battelle), and Universities strong in this area (OSU, UK, WVU, PSU, Princeton, VT, etc)
    - Strong state-level support and momentum in the industry, e.g. current infrastructure developments underway
- **Grid modernization** – smart grid and grid-scale electric storage (NEES EFRC, PJM, FirstEnergy, Exelon, AEP, NRG)
- **Energy Efficiency** – building and industrial efficiency (CBEI Hub, Energy4P32)
- **Nuclear Energy** – fission and fusion energy sciences (PPPL, WVU, Westinghouse, WastePD)
- **Advanced and Smart Manufacturing** (NNMIs: America Makes, IACMI, SMLC-CESMII)

Coal: Continued federal support of clean coal R&D is critical in the absence of market drivers. The region needs incentives to replace existing coal plants with ultra-supercritical coal combustion instead of natural gas-fired plants. Emphasis should be placed on adopting technologies. Carbon Capture and Storage technologies are still too immature for full commercialization and will require successful large-scale integration demonstrations before they can be successfully adopted.

Natural Gas: Due to the recent development in unconventional natural gas production from shales, a major opportunity to revolutionize the energy economy of the Mid-Atlantic Region is imminent. Two obvious natural gas technology R&D areas exist: de-carbonization with methane and natural gas conversion to other products. Opportunities may be realized by moving gas up the value chain, and we have the technology options to do this; it is not impossible to turn methane into other products. Gas is currently limited in end use. It is mostly used for power generation (about 90 percent of methane is used for this purpose). Components may be added to gas to enable a multitude of uses.

Low-carbon pathways: Perspectives for identifying and creating new low-carbon pathways to drive economic growth in the region were offered regarding both the creation of new, valuable products and the creation of a nexus of innovation capable of sustaining itself via a critical mass of technical capabilities to serve both domestic and international markets. The potential for advances in manufacturing techniques to both increase the advantage of U.S. manufacturers to produce conventional technologies as well as create a market advantage for those manufacturers to produce technology products of a specification not previously possible through traditional manufacturing techniques was discussed.

Nuclear Energy: Fusion is currently a global enterprise. The commercial deployment of fusion reactors is a long way off, but it will be a truly transformative carbon safe energy resource, as energy production from fusion is completely devoid of greenhouse gasses. Most of the issues facing nuclear fission energy center on time and cost—RD&D is time intensive and expensive and precludes investment by small venture capital companies. National laboratories have the capabilities but lack a means of conveying them. Advances and innovation in materials and in advanced manufacturing techniques using new materials can help alleviate these pressures.

Advanced Manufacturing: A strong innovation ecosystem has developed around advanced manufacturing in the Mid-Atlantic Region. Manufacturing and supply chain opportunities exist for all industries in the Mid-Atlantic States. The region can build on current expertise to innovate on a global scale, as there are many opportunities in additive manufacturing. Digital analytics for managing assets is an emerging area—there are new elements for software and digital analytics to drive efficiency across all power plants including focusing on uptime, in-situ monitoring, and power plant maintenance.

Economic Clusters: The Mid-Atlantic region is facing many of the same economic challenges that face rural economies across the United States: regional income dependency; regional imbalance in export GDP ratios; community by community competition; adverse impacts of regulatory changes; and declining labor participation. Industry clusters can make a significant contribution to regional economic growth by developing a robust, concentrated knowledge base in a particular industry and supporting industries, resulting in a competitive advantage; increasing the productivity of companies based in the area; driving the direction and pace of innovation; and stimulating the formation of new businesses, which expands and strengthens the cluster. The industry cluster approach identifies the competitive segments of an economy that can drive economic diversification and revitalization.

In summary, the energy system in the Mid-Atlantic Region has already begun a transition and in order to assure a smooth transition to a low-carbon, clean energy economy, robust partnerships across the region are necessary. Many of these partnerships have already been formed, and the region is rich in innovation and energy resources.

INTRODUCTION

The purpose of this report is to summarize the ideas presented and outcomes resulting from the Mid-Atlantic Region Energy Innovation Forum held on September 12, 2016, in Morgantown, WV at the West Virginia University (WVU) College of Law and sponsored by the WVU Energy Institute. The goal of the forum was to discuss the energy innovation ecosystem in the Mid-Atlantic region and share ideas for creating pathways to a cleaner energy future. The event engaged a diverse group of 122 participants from seven states (KY, OH, PA, VA, MD, NJ, WV, and DC) representing many interests in the future of clean energy, including representatives from academia (32), national laboratories (8), industry (35), government (22), and non-governmental organizations (15). The theme heard throughout many panel discussions was *partnerships*; additional themes included the need for advances in and de-carbonization of fossil fuel power production, support for clean energy policies, and the importance of investing in innovation and commercialization throughout the region.

The following sections summarize the themes and key ideas captured from each of the five panels held during the forum. The panels included Regional Challenges and Opportunities; Innovation Opportunities for Fossil Fuels in a Future Low Carbon Economy; Innovation Opportunities in Other Clean Energy Technologies; Policies Facilitating Sustainable Clean Energy Development; and Regional Innovation, Investment, and Commercialization.

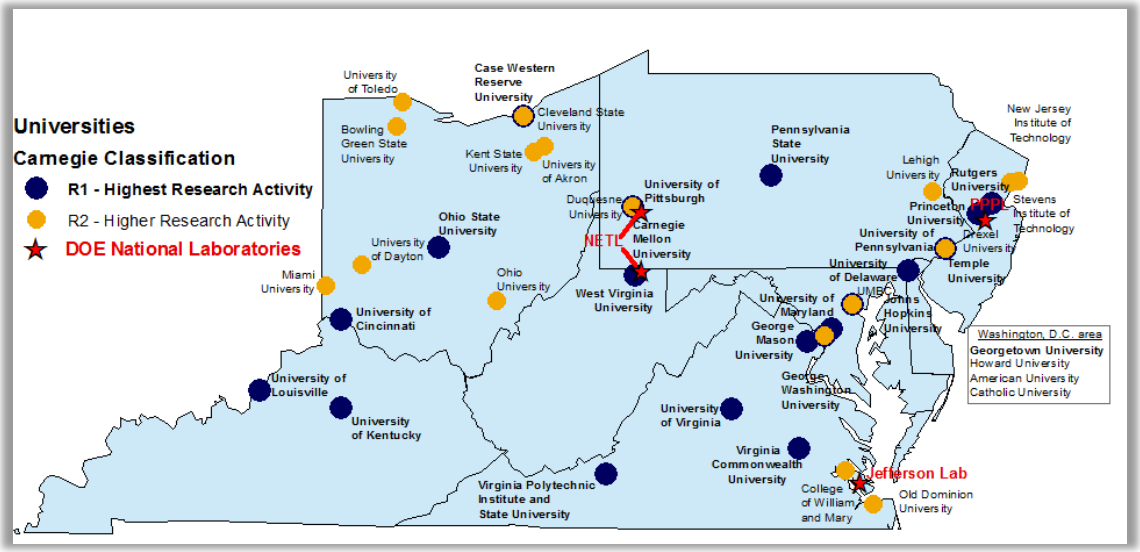


Figure 1 Mid-Atlantic Region Universities and National Labs

REGIONAL OVERVIEW

The Mid-Atlantic Region is blessed with abundant resources including oil, coal, and natural gas, and it is vital that these resources remain a part of the clean energy dialogue as our nation moves toward a new energy future. The region is also home to a diverse array of highly influential government and private research facilities and academic institutions, making it the epicenter of and the driving force for energy research. In addition, the region is home to the Longview Power Plant featuring an advanced supercritical boiler and many advanced industry standards that are now being employed globally (Figure 2).

Figure 2: Longview Power Plant

Natural resources—specifically fossil fuels—satisfy 80% of our nation's energy requirements; substantial regional power generation includes fossil, nuclear, and renewables.

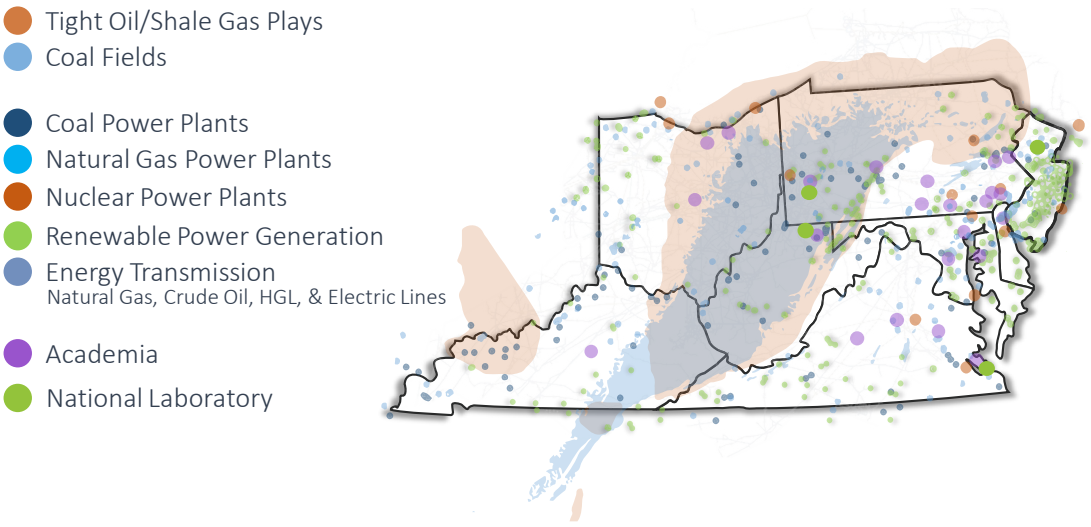


Figure 3: Regional Overview of Energy Resources and Power Generation

An energy overview of the Mid-Atlantic Region states is included below. (Source: EIA)

Delaware

The Delaware City refinery, with a capacity of about 182,200 barrels per day, is one of two coking refineries on the East Coast. Delaware generated 85% of its electricity from natural gas and 8% from coal in 2015.

Kentucky

Kentucky, the third-largest coal-mining state, produced more than 61 million short tons of bituminous coal in 2015. In 2015, 87% of Kentucky's net electricity generation was produced by coal and 7% by natural gas. Most of Kentucky's natural gas currently comes from the Big Sandy field in the eastern part of the state, but the Devonian Shale underlying two-thirds of Kentucky may contain more than 100 trillion cubic feet of

natural gas. Increasing amounts of customer-sited solar photovoltaic capacity have been installed across Kentucky, and the state is home to the nation's first net-zero energy public school.

Maryland

Maryland's Dominion Cove Point, the only liquefied natural gas import terminal in the Mid-Atlantic, is adding export capability at its Chesapeake Bay facility. Export operations are expected to begin in late 2017. In 2015, the Calvert Cliffs facility, Maryland's only nuclear power plant, supplied 40% of the state's net electricity generation. Independent power producers provided 98% of the net electricity generation in 2015. Maryland's Port of Baltimore has set coal-handling records in recent years, and in 2015, it was second in the nation in coal exports. Coal is the leading export commodity by tonnage leaving the Port of Baltimore.

New Jersey

In 2015, for the first time, natural gas generated more electricity in New Jersey than nuclear power. Together, the two fuels provided more than nine-tenths of the state's net electricity generation. Solar power became New Jersey's largest source of renewable electricity, with three-fifths of solar electricity generated from customer-sited solar panels in 2015.

Ohio

The Utica Shale has contributed to the rapid increase in natural gas production in Ohio, which was more than 12 times greater in 2015 than 2011. Ohio had the seventh largest crude oil refining capacity in the nation in 2015. Coal fueled 59% of Ohio's net electricity generation in 2015, natural gas contributed 23%, and nuclear energy accounted for another 14%.

Pennsylvania

Pennsylvania's annual gross natural gas production, primarily from the Marcellus Shale, exceeded 4 trillion cubic feet in 2014, doubling the state's 2012 production and making Pennsylvania the nation's second-largest natural gas producer. Pennsylvania was the fourth-largest coal-producing state in the nation in 2014 and the only state producing anthracite coal, which has a higher heat value than other kinds of coal. In 2015, Pennsylvania ranked second in the nation in electricity generation from nuclear power. The state obtained 37.2% of its net electricity generation from nuclear power, more than from any other source.

Virginia

At the end of 2013, Virginia was ranked fourth in coalbed methane proved reserves and had two natural gas fields that were ranked among the top 100 natural gas fields in the United States. The ports in the Norfolk Customs District—America's largest coal export center—processed more than 35% of U.S. coal exports in 2015. Natural gas provided 39% of Virginia's net generation in 2015, surpassing generation from the state's two nuclear power plants for the first time. The Virginia Department of Mines, Minerals, and Energy received the first federal offshore wind energy research lease issued by the U.S. Bureau of Ocean Energy Management.

West Virginia

West Virginia was the largest coal producer east of the Mississippi River and the second largest in the nation after Wyoming, accounting for 11% of the U.S. total coal production in 2013. In 2014, almost half

(50 million short tons) of the coal that was mined in West Virginia was shipped to other states and almost one-third (34 million short tons) was exported to foreign countries. In 2015, 94% of West Virginia's net electricity generation was produced by coal-fired power plants. West Virginia was also the eighth-largest natural gas-producing state in the nation, with more than 1.3 trillion cubic feet of natural gas production in 2015.

State	CO_2 Emissions		Oil and Natural Gas Reservoirs Storage Resource			Unmineable Coal Storage Resource			Saline Formation Storage Resource			Total Storage Resource		
	Million Metric Tons Per Year	Number of Sources	Billion Metric Tons			Billion Metric Tons			Billion Metric Tons			Billion Metric Tons		
			Low Estimate	Medium Estimate	High Estimate	Low Estimate	Medium Estimate	High Estimate	Low Estimate	Medium Estimate	High Estimate	Low Estimate	Medium Estimate	High Estimate
Delaware	9	18							0.04	0.04	0.04	0.04	0.04	0.04
Kentucky	99	122	1.05	1.75	3.21	0.14	0.18	0.2	14.72	46.43	110.2	15.91	48.36	113.61
Maryland	24	52	0	0	0	0	0	0	1.86	1.88	1.93	1.86	1.88	1.93
New Jersey	22	96							0	0	0	0	0	0
Ohio	126	231	0.65	1.08	1.97	0.12	0.12	0.12	9.91	9.91	9.91	10.68	11.11	12
Pennsylvania	132	281	0.8	1.34	2.45	0.27	0.27	0.27	17.34	17.34	17.34	18.41	18.95	20.06
West Virginia	71	84	5.93	9.84	18.05	0.37	0.37	0.37	11.19	11.19	11..19	17.49	21.4	29.61

Table 1. Carbon Dioxide Storage Potential for Mid-Atlantic Region

PANEL 1

Regional Challenges and Opportunities

Moderator:

Brian J. Anderson

Director, WVU Energy Institute, West Virginia University

Panelists:

Grace Bochenek

Director, National Energy Technology Laboratory, U.S. Department of Energy

Steven Winberg

Program Manager, Battelle Memorial Institute

Andrew Gellman

Co-Director, Wilton E. Scott Institute for Energy Innovation, Carnegie Mellon University

William Getty

President, Claude Worthington Benedum Foundation
Co-Chair, Power of 32

REGIONAL CHALLENGES AND OPPORTUNITIES

The Regional Challenges and Opportunities panel was moderated by ***Dr. Brian Anderson***, Director, Energy Institute, West Virginia University and included four panelists: ***Dr. Grace Bochenek*** (Director, National Energy Technology Laboratory, U.S. Department of Energy), ***Steven Winberg*** (Program Manager, Battelle Memorial Institute), ***Andrew Gellman*** (Co-Director, Wilton E. Scott Institute for Energy Innovation, Carnegie Mellon University), and ***William Getty*** (President, Claude Worthington Benedum Foundation; Co-Chair, Power of 32).

Something big is happening. Something big globally, nationally, and within our Mid-Atlantic Region. Nine days ago, history was made in Hangzhou, China. On Saturday, September 3, President Obama and Chinese President Xi Jinping formally committed the world's two largest economies to the Paris climate agreement, cementing their partnership on climate change and clean, low-carbon energy. Decreasing our carbon footprint is a challenge facing our region that has been built on the abundant fossil energy resources beneath us. We can only tackle this challenge through ***innovation and partnership****. Our region has always been at the forefront of energy innovation. In the mid-19th century, the first oil in the US was first produced in West Virginia and Pennsylvania. In 1886, George Westinghouse found his company competing for developing the earliest electric infrastructure in the US. I believe that our region is not only the breadbasket of energy resources but also energy innovation.*

Synopsis

The Mid-Atlantic Region is blessed with abundant fossil energy resources upon which its economy heavily depends. However, continuing the rich history of fossil energy development in this region requires innovative research and technology to help offset an aging energy infrastructure. Eighty-percent of coal is burned in units over 30 years old; plant age and environmental regulations make capital investments harder to justify.

Partnerships among academia, nonprofit institutions, national laboratories, and industry are key to solving many of these challenges. As the U.S. government's only national laboratory dedicated to fossil energy research, NETL must build its capabilities for fossil fuel technology research, development, and demonstration through innovation and partnerships. Moving forward, the coal industry, utilities, and independent power providers must work together to advance coal technology with the coal industry taking the lead to build pilot plants on mine property.

This region has many opportunities to utilize its resources, with a specific opportunity being the conversion of natural gas into value-added chemicals. The region must realize the full value of the resource, which will require investment as well as technology innovation.

While many opportunities exist, so do many challenges, including the need for technology incubator space and capital, which can be hard to come by with few entities willing to invest in innovation with higher yields and risks. Energy technology development requires new hardware and has a delayed return on investment, both of which make it much more challenging for the region to fully utilize its natural resources.

The Mid-Atlantic Region has an advantage in that it reinventing its electrical grid and is in close proximity to an enormous marketplace. Power transmission is the highest-cost element of the value chain, and the region is within 700 miles of 70 percent of North America's population.

The region must have a workforce development system that provides workers with the skills they need to both obtain initial employment and advance their careers within the industry.

The electricity grid of the Mid-Atlantic Region is largely served by the PJM Interconnect and has undergone significant changes since 2011, including 24,000 MW_e of capacity retirements with 2,600 MW_e of retirements pending. The PJM Interconnection and the capacity retirements are shown in Figure 4.

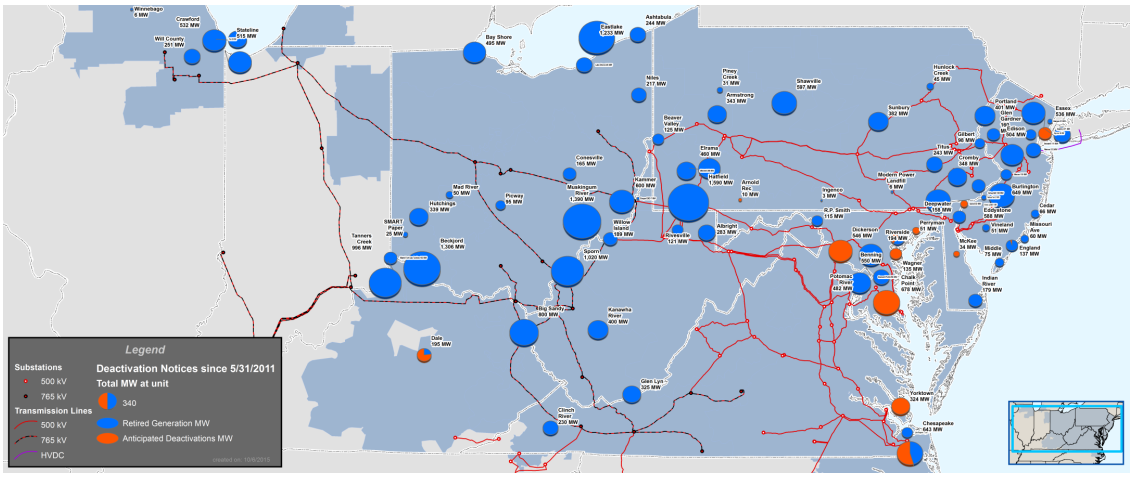


Figure 4: Generation Retirements in the PJM Interconnection since 2011 (Presenter: Gary Helm)

Next generation coal technologies with Carbon Capture & Sequestration started at the National Energy Technology Laboratory. The region needs to proceed in a very aggressive manner. The coal industry can no longer rely on utilities to advance technologies. They have other less expensive options, have higher priority uses of their capital, and many have mandates to reduce coal consumption. The coal industry must partner with technology providers and build the pilot plants. New, next generation coal technologies are being developed at NETL and other regional partners, examples are shown in Figure 5.

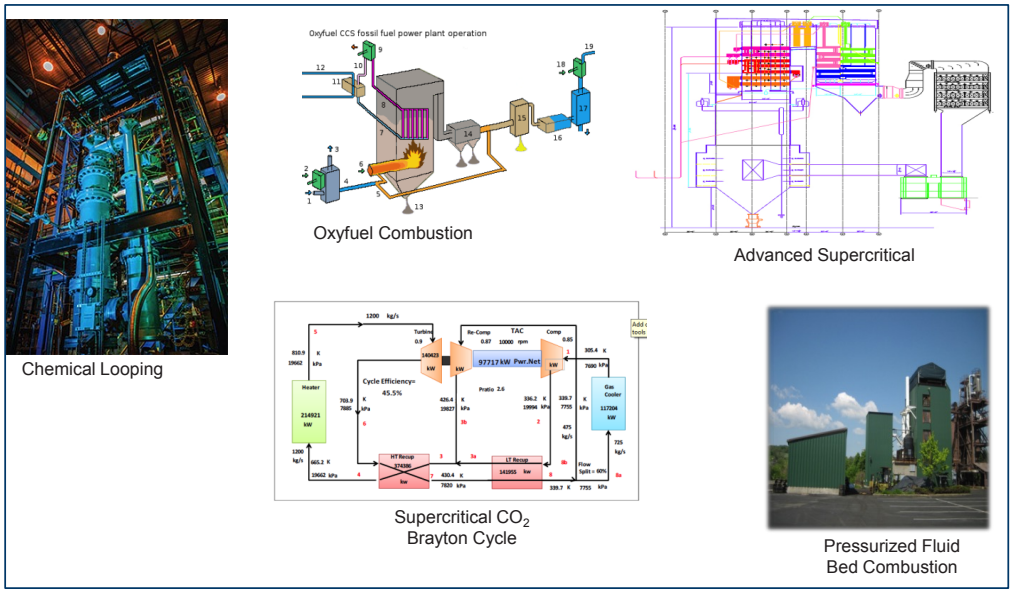


Figure 5: Next Generation Coal Technologies with Carbon Capture and Sequestration (Presenter: Steve Winberg)

OPEN DISCUSSION

THE FUTURE OF CLEAN ENERGY

Joe Manchin, III
U.S. Senator, West Virginia
Introduction by E. Gordon Gee
President, West Virginia University

David B. McKinley, PE
U.S. Representative, WV 1st Congressional District
Introduction by Grace Bochenek
Director, National Energy Technology Laboratory

Ernest J. Moniz
U.S. Secretary of Energy
Introduction by Joe Manchin, III
U.S. Senator, West Virginia

The Future of Clean Energy

Panelists: Joe Manchin (U.S. Senator, WV), David McKinley (U.S. House of Representatives, WV), and Ernest J. Moniz (U.S. Secretary of Energy).

Synopsis

Regional focus on innovation is key and will impact how the region structures innovation moving forward. Deep innovation for de-carbonization is needed in this century and beyond. How can we help transition the economy as we move toward clean energy?

Concerns revolve around energy reliability, affordability, and availability in the region. Will affordable, reliable energy be abundant in the future? Our region is investing in clean coal technologies, but the private sector has not stepped up and will not until they have a certain/secure path forward.

Lower carbon emissions do not mean discontinuing the use of fossil fuels. The coal sector has been strongly impacted in this region. The enormous production of low-cost natural gas has created an energy revolution with West Virginia producing 1.3 trillion cubic feet of natural gas.

Diversification makes a big difference in a utility's portfolio. Utilities need signals now in order to make sound investment decisions on coal utilization with carbon capture (utilities base their projections on 10-year timescales). Fossil energy is still in the mix until 2040 and will be a dominant driver for the foreseeable future. The question is, how do we use fossil energy better? Can we retrofit existing plants to make them able to compete?

Looking toward the future, we must invest in game-changing technology that could have enormous impact on the ways coal can be used in low-carbon environments. For example, CO_2 plus water plus sunlight could replace hydrocarbons for fuel.

Tax credits for wind and solar should be instituted in areas in West Virginia where there is economic disparity. The state is looking for an incentive/cost to dial back into industry to help drive this region. We need to move tax credits to most affected areas. For example, six West Virginia counties are experiencing a depression, and need partners to move forward. In addition, the region's coal miners are concerned about the inability to fulfill promises in 1946 legislation that they would receive benefits and pensions, a situation that could affect 23,000 miners.

Tri-State Governors' Regional Cooperation

Panelists: ***Chris Stadelman*** (Chief of Staff to West Virginia Governor Tomblin), ***Dennis Davin*** (Secretary, Pennsylvania Department of Community and Economic Development)

The governors of Ohio, West Virginia, and Pennsylvania have agreed to collaborate on natural gas and shale gas exploitation. The action plan is designed to maximize economic opportunity to attract downstream manufacturing because value increases further down the value chain. The governors understand that the region has a competitive research presence in physics, geology, chemistry, robotics, additive manufacturing, and information technology, and that our regional universities must collaborate leverage these capabilities to further advance research and technology in these areas.

Synopsis

Opportunities for energy development began with coal, but none are like shale gas, which could be a game changer in this region. Working groups are currently researching Marcellus and Utica shale gas. The states are working with partners to determine how to move forward with production, storage, and transport of shale gas.

The three states are collaborating to create a tri-state shale gas industry. Challenges include getting natural gas to market (many wells have been shut in due to lack of pipeline infrastructure). The states must quickly build a safe, sustainable, efficient, and world-class pipeline infrastructure to enable the region to realize the full value of the resource. Ten billion dollars in infrastructure is needed for natural gas pipelines and other infrastructure and many companies are in the queue. Gas extraction is important, but downstream development is important as well. Shell is building a cracker plant in Beaver County, Pennsylvania that will benefit the entire region. Crackers could be built in Wood County, West Virginia and other counties, which could benefit all three states. The Appalachian Basin and region is capable of competing with the Gulf Coast; the region's access to the natural resource and proximity to end users provide a great opportunity for full life cycle benefit in terms of environmental sustainability and economic competitiveness.

The Governor's agreement among Ohio, WV, and PA is to collaborate on natural gas and shale gas. This action plan is designed to maximize economic opportunity to attract downstream manufacturing. Value flows as you advance down the value chain; must use the product here (manufacturing). Governors understand we have a competitive research presence in physics, geology, chemistry, robotics, additive manufacturing, IT; important that these universities are collaborating around research. Access to R&D can be an attraction for businesses to do manufacturing because energy costs are down in this region and nationwide.

PANEL 2

Innovation opportunities for fossil fuels in a future low carbon economy

Moderator:

Sean Plasynski

Executive Director, Technology Development & Integration Center, National Energy Technology Laboratory

Panelists:

James Bielenberg

Corporate Strategic Research, ExxonMobil Research and Engineering

Neeraj Gupta

Senior Research Leader, Battelle

Dave van der Wiel

Director, Babcock & Wilcox Research Center

David Zaziski

Vice President, Siluria

INNOVATION OPPORTUNITIES FOR FOSSIL FUELS IN A FUTURE LOW CARBON ECONOMY

Moderator: Sean Plasynski (NETL)

Panelists: James Bielenberg (ExxonMobil), Neeraj Gupta (Battelle Memorial Institute), Dave van der Wiel (Babcock & Wilcox Research Center), and David Zaziski (Head of Government Affairs, Siluria Technologies)

This panel discussed the technical challenges and opportunities for innovation in utilizing coal and gas. Recognizing the technical challenges associated with coal and gas utilization for electric power generation, the panel focused its comments on opportunities to significantly improve power generation processes, such as novel approaches to conversion and combustion via chemical looping and oxy-combustion technologies as well as the materials needed for creating ultra-supercritical steam conditions at coal-fired power plants. Because these technologies still result in significant amounts of CO_2 emissions, CO_2 capture and storage innovation opportunities were also discussed. In addition, the panel explored potential technology innovations for utilizing natural gas. Topics spanned new conversion pathways of natural gas and natural gas liquids. Shale gas development in the region has spurred greater interest in new products, processes, and uses for natural gas.

Synopsis

Continued federal support of clean coal R&D is critical in the absence of market drivers. The region needs incentives to replace existing coal plants with ultra-supercritical coal combustion instead of natural gas-fired plants. Emphasis should be placed on adopting technologies. Carbon Capture and Storage technologies are still too immature for full commercialization and will require successful large-scale integration demonstrations before they can be successfully adopted. Corporate investments are not possible without a near-term market beyond enhanced oil recovery.

Oxy-combustion and chemical looping technologies are promising and progressing well. High-temperature ultra-supercritical materials expertise feeds directly to supercritical CO_2 cycles. With respect to CO_2 capture technology, membrane processes are technically and financially attractive and are transferable to many applications and markets. Advances in coal chemical looping transfer directly to natural gas conversion. Burning natural gas wastes its chemical potential.

Two obvious natural gas technology R&D areas exist: de-carbonization with methane and natural gas conversion to other products. Opportunities may be realized by moving gas up the value chain, and we have the technology options to do this; it is not impossible to turn methane into other products.

Gas is currently limited in end use. It is mostly used for power generation (about 90 percent of methane is used for this purpose). Components may be added to gas to enable a multitude of uses.

Three areas of methane R&D are materials and process concepts for light-molecule separation, theoretical and experimental scoping of catalytic materials, and advanced concepts in reactor engineering and process intensification.

Methane is the world's most-used building block for petrochemicals. Economies of scale result in world-class facilities that cost many billions to construct. Few companies can finance these, but there is a cluster of such large facilities on the U.S. Gulf Coast.

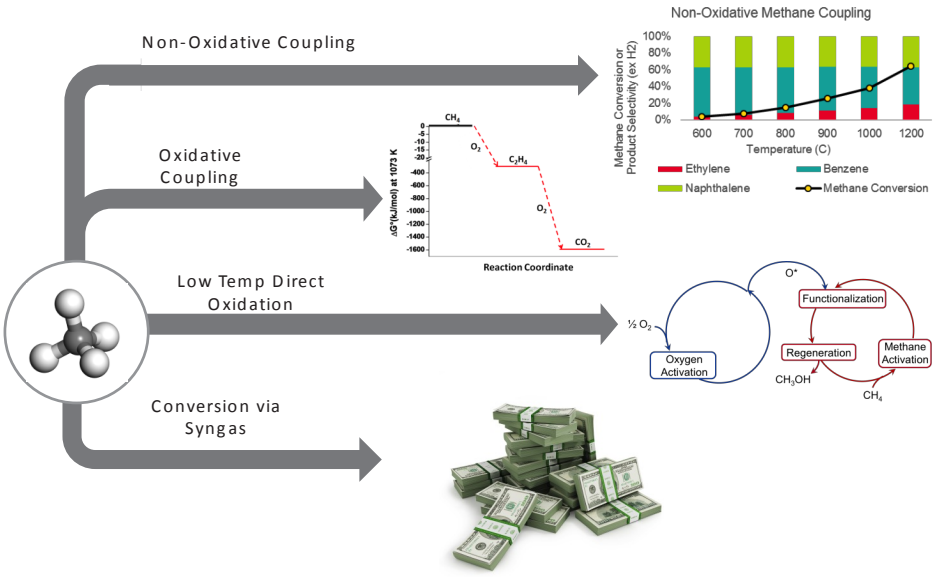


Figure 6: Four routes for conversion of methane (Presenter: James Bielenberg)

Siluria Technologies has a breakthrough catalytic oxidative coupling process for methane conversion to petrochemicals and cleaner liquid fuels, producing high-value products from low-value carbon sources. Siluria claims the process is the world's only pathway to produce (1) ethylene from natural gas, (2) ethylene on a distributed scale, and (3) liquid fuels directly (i.e., non-syngas) from natural gas. Inputs are methane (or ethane) plus air, enriched air, or O_2, and outputs are ethylene plus water plus heat. A demonstration plant has been built in La Porte, Texas.

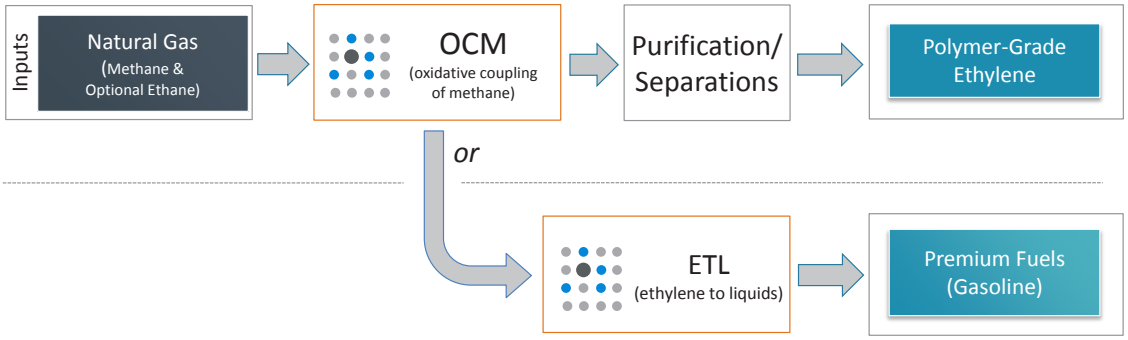


Figure 7: Siluria pathways of conversion of methane through oxidative coupling of methane (Presenter: David Zaziski)

The Midwest Regional Carbon Storage Partnership is one of seven Regional Geologic Sequestration partnerships collaborating with energy companies, universities, and other industries to capture carbon

dioxide created in energy production and industrial processes and store it safely underground in natural geological formations. Work is ongoing under Phase III (Development). Past and present work includes geologic carbon storage projects in Illinois, Ohio, and West Virginia; assessment of wellbore integrity, simplified modeling for CO_2 storage, mid-Atlantic offshore storage, brine disposal in the Appalachian Basin, and development of a geomechanical framework for fluid injection. The partnership is working with state geologic surveys to build a map of potential CO_2 storage sites across ten states (Figure 7) and has done characterization work with natural gas and brine industries to identify new storage horizons. Carbon dioxide utilization in Ohio oilfields is also of interest.

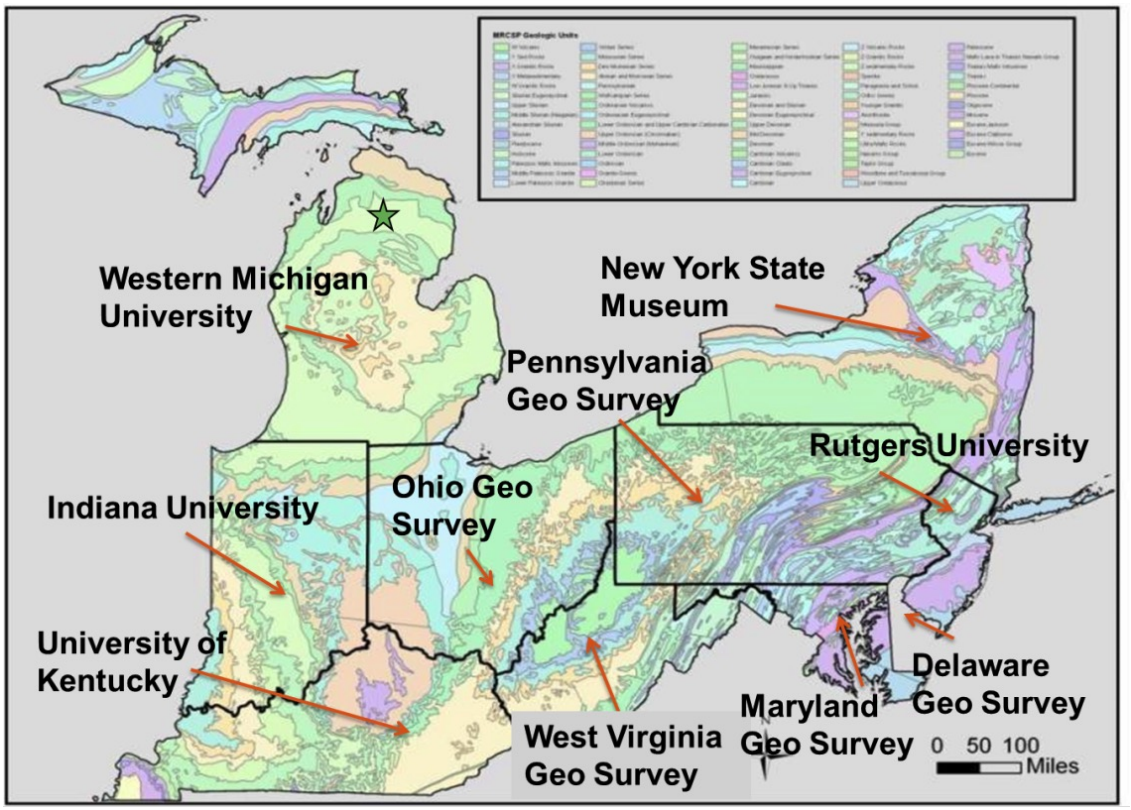


Figure 8: Regional Characterization – A Geologic Storage Potential Mapping Collaboration (Gupta, Battelle)

PANEL 3

Innovation opportunities in other clean energy technologies

Moderator:
Court Gould
Executive Director, Sustainable Pittsburgh

Panelists:
Stewart Prager
Director, Princeton Plasma Physics Laboratory
Edward Herderick
GE Corporate Supply Chain and Operations
Denise Swink
Chair, Smart Manufacturing Leadership Coalition
Michael N. Worley
Director, Innovative Nuclear Research, U.S. Department of Energy

INNOVATION OPPORTUNITIES IN OTHER CLEAN ENERGY TECHNOLOGIES

The Innovation Opportunities in Other Clean Energy Technologies panel was moderated by ***Court Gould***, Executive Director, Sustainable Pittsburgh and included four panelists: ***Stewart Prager***, Director, Princeton Plasma Physics Laboratory; ***Edward Herderick***, GE Corporate Supply Chain and Operations; ***Denise Swink***, Chair, Smart Manufacturing Leadership Coalition; and ***Michael N. Worley***, Director, Innovative Nuclear Research, U.S. Department of Energy.

This panel discussed potential opportunities for identifying and creating new low-carbon pathways to drive economic growth in the region. Perspectives were offered regarding both the creation of new, valuable products and the creation of a nexus of innovation capable of sustaining itself via a critical mass of technical capabilities to serve both domestic and international markets. The potential for advances in manufacturing techniques to both increase the advantage of U.S. manufacturers to produce conventional technologies as well as create a market advantage for those manufacturers to produce technology products of a specification not previously possible through traditional manufacturing techniques was discussed.

Synopsis

The Smart Manufacturing Leadership Coalition is working to invigorate a better supply chain, meet manufacturing challenges, and create innovative approaches on the enterprise level. The majority of manufacturing is still not technologically sound, and there is a need to increase the focus. A group of companies has collaborated to build a prototype for a smart manufacturing database of hardware and software to solve manufacturing problems while creating a lively marketplace. Users would pay only for the products they need without being locked into a single technology. The database would be on a cloud-based platform to ensure continuity. From an energy perspective, most manufacturing is designed to an energy efficiency level only after the utility bills are paid. If manufacturers are given the tools and capabilities, they can drive down the risk of employing new technologies.

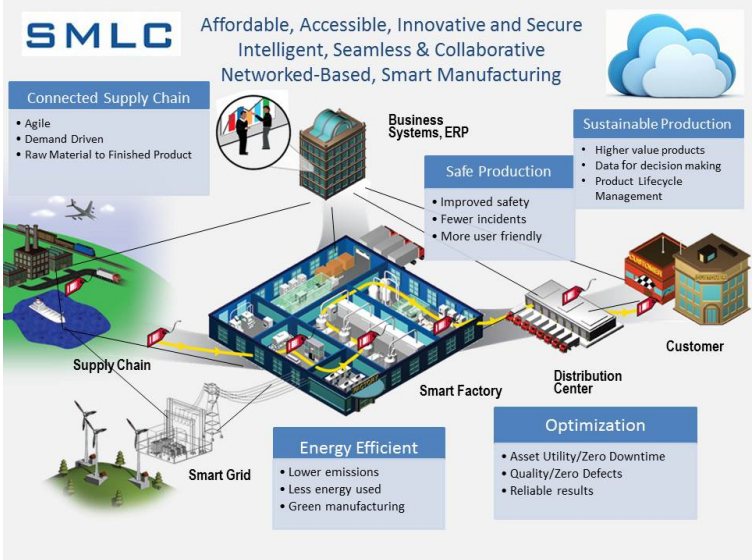


Figure 9: Smart Manufacturing Platform (Courtesy: SMLC)

Fusion is currently a global enterprise. The commercial deployment of fusion reactors is a long way off, but it will be a truly transformative carbon safe energy resource, as energy production from fusion is completely devoid of greenhouse gasses. The industry is still immature because fusion technology is very difficult to create and funding has never been sufficient to build the test beds needed. The ITER facility—an international collaboration in the southern France that will be operational in 10 years—will generate 500 MW of fusion for eight minutes at a time (see Figure 9). The United States is nine-percent partner, and $4–5 billion is being spent in the United States fabricating components.

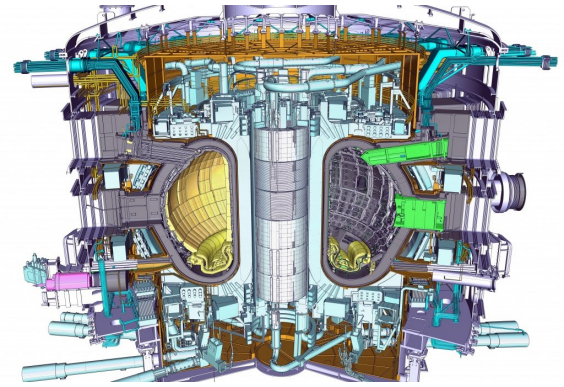


Figure 10: A detailed model of the ITER Tokamak. Image credit: ITER Organization 2011

A strong innovation ecosystem has developed around advanced manufacturing in the Mid-Atlantic Region. Manufacturing and supply chain opportunities exist for all industries in the Mid-Atlantic States. The region can build on current expertise to innovate on a global scale, as there are many opportunities in additive manufacturing. Digital analytics for managing assets is an emerging area—there are new elements for software and digital analytics to drive efficiency across all power plants including focusing on uptime, in-situ monitoring, and power plant maintenance.

Most of the issues facing nuclear energy center on time and cost—RD&D is time intensive and expensive and precludes investment by small venture capital companies. National laboratories have the capabilities but lack a means of conveying them. Plant design and licensing of nuclear power plants is slow right now and there is a need to make nuclear capabilities, computational capabilities, and modeling and simulation tools available. A pilot voucher system to make funds available has been initiated. One of the biggest barriers is that small startup firms don't have the resources to invest in nuclear energy. However, partnering with EPRI for powdered metal and other additive manufacturing could make nuclear energy a viable option if costs are decreased (Figure 11).

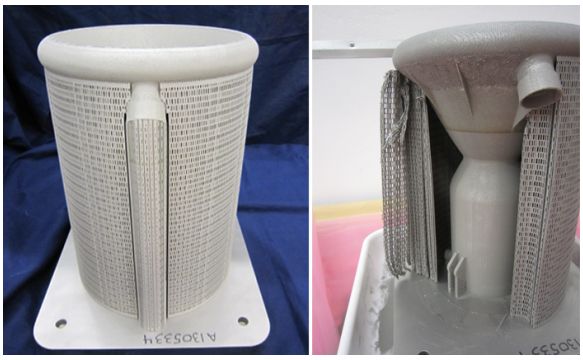


Figure 11: This rocket engine was printed whole using a powder bed additive manufacturing process. It is the first prototype rocket engine for the proposed NX-01 Nanosat Launch vehicle. It was manufactured in 8 days at a cost of $10,000 (LLNL)

PANEL 4

Policies Facilitating Sustainable Clean Energy Development

Moderator:

Scott Rotruck

Director of Energy & Transportation Services, Spilman Thomas & Battle

Panelists:

Jan Mares

Senior Policy Advisor, Resources for the Future

Gary Helm

Lead Market Strategist, PJM Interconnection

Mike Casper

Senior Manager, Generation and Fuels, National Rural Electric Cooperative Association

POLICIES FACILITATING SUSTAINABLE CLEAN ENERGY DEVELOPMENT

The Policies Facilitating Sustainable Clean Energy Development panel was moderated by ***Scott Rotruck***, Director of Energy and Transportation Services, Spilman Thomas & Battle, and included three panelists: ***Jan Mares***, Senior Policy Advisor, Resources for the Future; ***Gary Helm***, Lead Market Strategist, PJM Interconnection; and ***Mike Casper***, Senior Manager, Generation and Fuels, National Rural Electric Cooperative Association.

The panel discussed the opportunities and challenges inherent in creating policies to facilitate sustainable clean energy development in the Mid-Atlantic Region. Options discussed included the use of grass roots campaigns, regulations, subsidies, jobs programs, and technology initiatives to spur growth in the energy sector. The panel also discussed how market changes can profoundly impact the energy landscape, affecting company decision making and policies regarding future clean energy investments.

Synopsis

Citizens—by influencing their elected and appointed leaders, friends, colleagues and for-profit and not-for-profit organizations—by publicly stating positions in support of relevant policies and, as appropriate, implementing same; and governments—by supporting and implementing relevant policies, to the extent budgets allow—can all facilitate clean energy development. In addition, clean energy development requires policies that support public and private sector efforts to inform the public about potential threats from and means of addressing climate change; research to determine the effectiveness of "clean energy" technologies and energy efficiency policies as a means of making them more effective; and continued federal support for "clean energy" R&D. Other polices that facilitate clean energy development include continued efforts to promote energy efficiency including regulation, training workers for new occupations; increasing the price of carbon emissions, which will drive changes in business activities and investments in low-carbon manufacturing goods and services; and early adoption of clean energy technologies and services by the government.

PMJ Interconnection operates a high voltage grid in the Mid-Atlantic region, and shale gas has dramatically changed the economics of the company. PMJ Interconnection is focusing on markets that foster innovation and innovative technologies that may prove valuable in the marketplace. Subsidies may work at odds with the market by distorting price signals and inhibiting innovation. The energy market trends are changing: nuclear and gas are at the highest levels and coal is at the lowest, wind is increasing, and waste and hydro are steady. Coal production decreased after early 2015, with oil and gas expected to increase drastically. Other technologies will be coming online provided they are economically viable; however, 80 percent of market additions since 2007 have been gas. Overall, coal is down and natural gas, nuclear, and renewables are up.

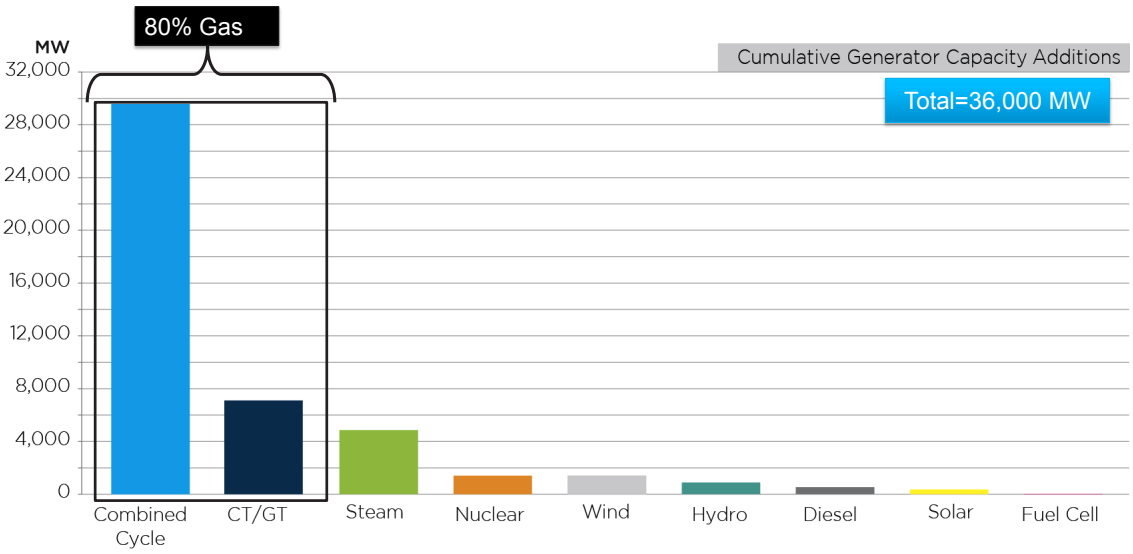


Figure 12: PJM Capacity Market Additions since 2007/2008 (Helm, PJM)

Rural areas comprise 11 percent of power consumption, but they are an integral part of energy generation. The energy landscape has changed from 2015 to 2016—the extension of ITC/PTC (which led to a 20–25 percent increase in renewables) and low natural gas prices (expected to remain in the $3–5 range or less) will reduce coal power generation by 17 percent from 2016–2040 and CO_2 emissions by 16 percent. Strategic solutions include keeping fossil generation viable, environmentally beneficial electrification, and developing local options. In addition ,the "Community Storage Initiative," an inclusive national market development collaborative has garnered the support of the electric utility industry, the environmental community, the renewable energy industry, and the public policy community.[1] The Grid Ballast Project (ARPA-E)—a project to develop an electronic device to help create autonomous frequency regulation to respond in real-time without communications and built into consumer electronics—may revolutionize our energy infrastructure. Natural gas could be the next coal just as coal was in the past; however, we must not prematurely write off energy sources. Innovation means thinking outside of the box, and with the right amount of innovation, natural gas could be a game changer.

[1] https://www.law.umn.edu/events/community-storage-initiative-2016-leadership-forum

PANEL 5

Regional Innovation Investment and Commercialization

Moderator:

Mike Green

Chairman, West Virginia Growth Investment Fund

Panelists:

Jeffrey McDaniel

Executive-in-Residence, Innovation Works

Joseph Hezir

Chief Financial Officer, U.S. Department of Energy

Mark Nydam

Principal, HarbourVest Partners,
Executive Chairman Accordant Energy

REGIONAL INNOVATION INVESTMENT AND COMMERCIALIZATION

The Regional Innovation Investment and Commercialization panel was moderated by ***Mike Green***, Chairman, West Virginia Growth Investment Fund, and included three panelists: ***Jeffrey McDaniel***, Executive-in-Residence, Innovation Works; ***Joseph Hezir***, Chief Financial Officer, U.S. Department of Energy; and ***Mark Nydam***, Principal, HarbourVest Partners, Executive Chairman Accordant Energy.

The moderator, Mike Green, began the session by noting that there is very little venture capitalism in the Mid-Atlantic region. The panel responded by discussing the drivers needed and programs that have been implemented to attract venture capital.

Synopsis

Innovation Works is an early, state seed investor created to identify startups and concepts that are right for investment. They are part of the Ben Franklin technology partnership and are non-profit, but they do focus on energy and manufacturing and model the for-profit venture space instead of taking a more traditional stance. They subscribe to the "all of the above" approach from an energy and portfolio perspective. The biggest issue preventing a continuously growing innovation pipeline is the growing influx of good ideas without enough capital to motivate it. Partnering (public and private) is crucial and access to resources means more than just capital, it means providing test beds to prove concepts. Regional development is also important—most starter companies will make it by selling their products in a region other than this one. The investment community needs to increase its energy IQ, and we all need to work on educating the workforce to understand the impacts energy has on all of us.

Energy commercialization is both an outcome and a driver of the innovation process (Figure 13). There are two commercialization incentives: CCUS tax credits and loan guarantees. A Future of Natural Gas study showed that a lot of research was conducted following increased regulations in 1970s, which then moved to the private sector with GRI funding and was steady over 16 years. A time limited tax credit was implemented under which production progressed slowly but steadily. Natural gas production boomed once enough technologies matured (Figure 14).

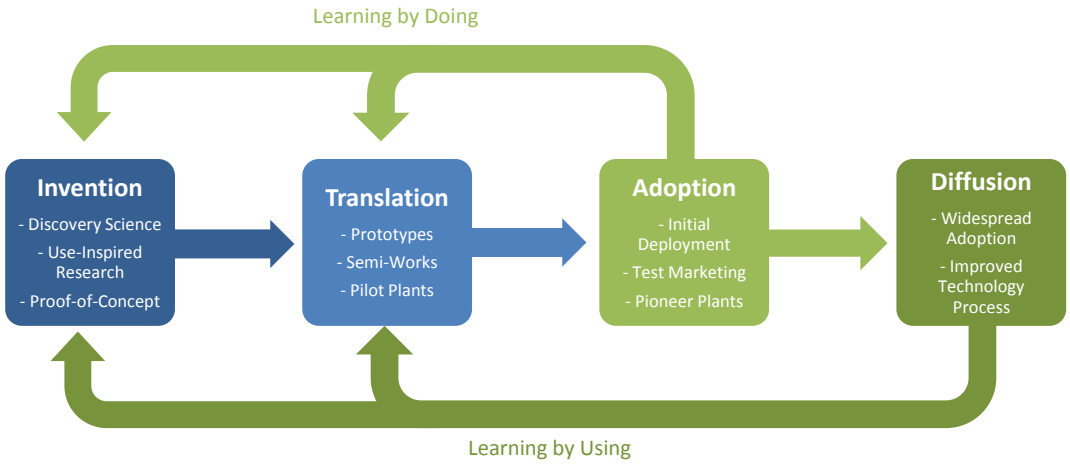


Figure 13: Commercialization as Both an Outcome and Driver of the Innovation Process (Hezir, from Ed Rubin, CMU)

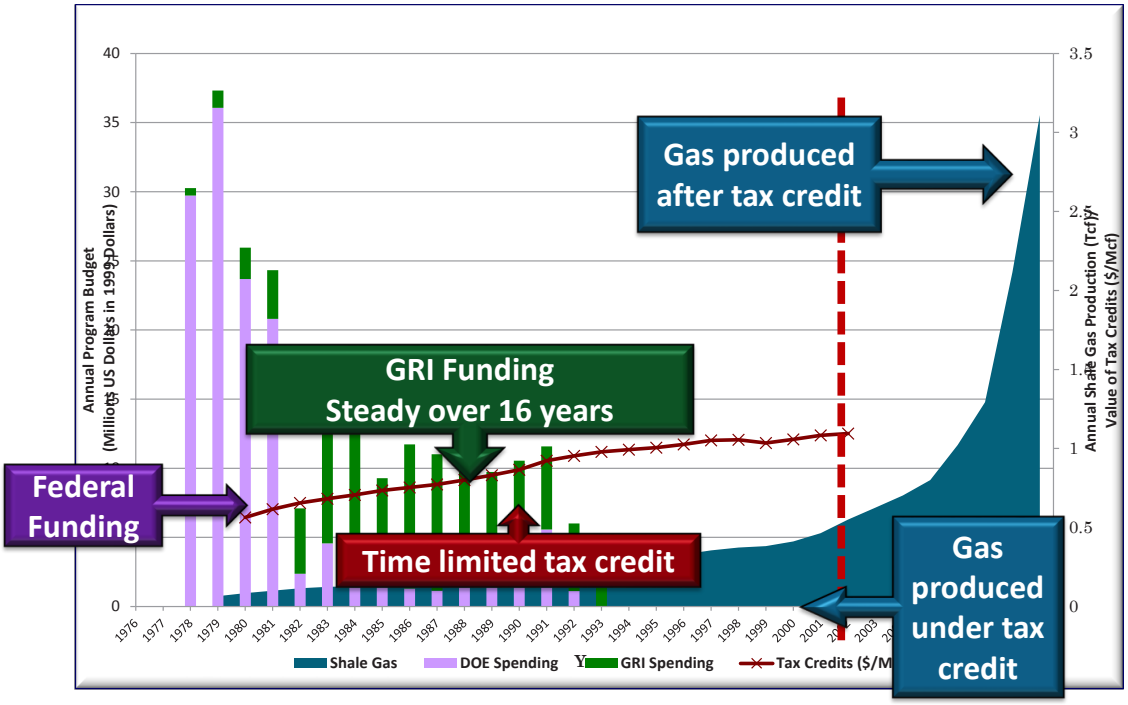


Figure 14: Innovation Experience for Unconventional Gas Development (Hezir, Source: MIT Future of Natural Gas)

Tax incentives complement innovation as the Investment Tax Credit (ITC) reduces up-front investment in CCUS by 30 percent and the Sequestration Tax Credit (STC) results in $3.8/MWh cost savings for every $10/ton of carbon sequestered. DOE modeling analysis found significant commercial market potential. Modeling can incentivize 30 GW of coal and natural gas CCUS by 2030 and up to 50 GW by 2040. It also provides options for CO_2—beneficial use vs. non-beneficial use. There is also DOE credit authority available for a wide range of innovative technologies. There is more than $40 billion in remaining authority: advanced

vehicle technologies ($16 billion), advanced fossil energy ($8.5 billion), renewable energy ($4.5 billion), and advanced nuclear energy ($12.5 billion).

The technology areas of interest for advanced fossil energy loan guarantees include:

Advanced Resource Development

Coal-bed methane recovery

Novel oil and gas drilling

Low Carbon Power Systems

Chemical looping or process that isolate fuel form air during combustion

Fuel cells which convert chemical energy into electricity without combustion

Carbon Capture

Carbon dioxide capture from traditional coal or natural gas electricity generation

Permanent geologic storage or utilization in enhanced oil recovery (EOR)

Efficiency Improvements

Combined heat and power (CHP) and industrial waste recovery

High-efficiency distributed fossil power systems and microgrids

Federal tax incentives and loan guarantees can provide significant benefits to early adopters of advanced fossil energy technologies and are an important complement to state and local government incentive packages. Commercialization/deployment/diffusion are integral elements of an effective energy technology innovation strategy—both as an outcome and a driver of innovation.

The Mid-Atlantic region is facing many of the same economic challenges that face rural economies across the United States: regional income dependency; regional imbalance in export GDP ratios; community by community competition; adverse impacts of regulatory changes; and declining labor participation. Industry clusters can make a significant contribution to regional economic growth by developing a robust, concentrated knowledge base in a particular industry and supporting industries, resulting in a competitive advantage; increasing the productivity of companies based in the area; driving the direction and pace of innovation; and stimulating the formation of new businesses, which expands and strengthens the cluster. The industry cluster approach identifies the competitive segments of an economy that can drive economic diversification and revitalization. Examples for the Mid-Atlantic Region include coal, technology, manufacturing, agriculture, tourism, and timber. However, successful application in rural areas creates certain challenges: expanded geographies mean more upfront effort to identify opportunities for and facilitate collaboration; rural collaboration is difficult due to more traditional views; difficulty in understanding that economic success is not a zero-sum game; and the willingness of local leaders to identify opportunities, drive change, and lead the effort to overcome the “victim mentality.” The components of the regional approach include a financing facility, an economic development plan, and business incubator networks. The benefit of this approach is that it facilitates innovation from a practical business standpoint that makes economic sense and drives economic growth.

CONCLUSION

The Mid-Atlantic Region's diverse population of 55 million people, and its robust energy resource base makes it unique. The western half of the region is blessed with abundant fossil energy resources, particularly coal and natural gas, while the eastern half of the region hosts the majority of the population. At the forum, engaged representatives from 7 of the 8 states in the region participated from all sectors of the energy ecosystem: academia, industry, national laboratories, government (federal, state, and local), and non-governmental organizations.

The forum highlighted the need for innovation within the economies of the Mid-Atlantic Region that have historically been based heavily on fossil energy resources. It is through partnerships and collaboration that innovations across the energy innovation ecosystem will be uncovered.

Five priority innovation focus areas emerged:

- **Clean fossil**: advanced power cycles, fuel cells, CCUS, and increased natural gas utilization
  - NETL, Industry partners (i.e. B&W, ExxonMobil, Siluria, Battelle), and Universities strong in this area (OSU, UK, WVU, PSU, Princeton, VT, etc)
  - Strong state-level support and momentum in the industry, e.g. current infrastructure developments underway
- **Grid modernization** – smart grid and grid-scale electric storage (NEES EFRC, PJM, FirstEnergy, Exelon, AEP, NRG)
- **Energy Efficiency** – building and industrial efficiency (CBEI Hub, Energy4P32)
- **Nuclear Energy** – fission and fusion energy sciences (PPPL, WVU, Westinghouse, WastePD)
- **Advanced and Smart Manufacturing** (NNMIs: America Makes, IACMI, SMLC-CESMII)

Federal tax incentives and loan guarantees can provide significant benefits to early adopters of advanced fossil energy technologies and are an important complement to state and local government incentive packages. Commercialization/deployment/diffusion are integral elements of an effective energy technology innovation strategy—both as an outcome and a driver of innovation.

The power grid in the region, managed by PJM, has seen significant change in the capacity base, and additional strain due to large generation retirements. Much of the capacity shift has moved from coal to natural gas. Advances in grid technologies are paramount in ensuring reliability into the future as the generation base becomes more diverse.

In summary, the energy system in the Mid-Atlantic Region has already begun a transition and in order to assure a smooth transition to a low-carbon, clean energy economy, robust partnerships across the region are necessary. Many of these partnerships have already been formed, and the region is rich in innovation and energy resources.

APPENDICES

A. Regional Partnerships

REGIONAL CLEAN ENERGY INNOVATION PARTNERSHIPS
FY 2017 Congressional Budget Request

To accelerate clean energy innovation and commercialization in the U.S., the Department of Energy is establishing a new Crosscutting Innovation Initiative program in FY 2017. This program will fund research, development, and demonstration (RD&D) activities that will strengthen regional clean energy innovation ecosystems; accelerate next-generation clean energy technology pathways; and encourage clean energy innovation and commercialization collaborations between our National Laboratories and American entrepreneurs. As a part of this program, $110 million is requested to support a new competition to establish up to 10 **Regional Clean Energy Innovation Partnerships (RCEIPs)** around the country, cost-shared with state, industry, academic, and other stakeholder partners.

The U.S. energy system is composed of regions with unique energy needs and opportunities. The goal of this subprogram is to accelerate the pace of innovation in clean energy technologies through the cost- shared, technology neutral partnerships that fund RD&D to address the clean energy challenges and opportunities specific to regional energy resources, policies, customer needs, markets and the innovation capabilities of various regions of the country.

A regional approach to innovation is responsive to the conclusion of The National Research Council 2012 Report, *Rising to the Challenge*, noting that "Historically, federally funded R&D has not been connected to state and regional industrial development. Bridging that gap can create the local talent and technology base needed to convert these U.S. investments into domestic companies, industries and jobs." Regional Clean Energy Innovation Partnerships complement national level RD&D efforts.

Specific benefits of this approach include:

- Leveraging existing knowledge clusters and comparative strengths of a geographic region;
- Linking the needs of industry and energy decision-makers with technical resources and expertise at universities and laboratories to enhance clean energy technology commercialization, economic development, and manufacturing;
- Sharing risks and pooling resources between the public and private sector to conduct RD&D projects with sustained and predictable funding; and
- Allowing for the development of new pathways for RD&D involving nonfederal stakeholders and other performers not typically engaged through existing DOE programs.

In FY 2017, DOE will solicit and competitively select up to 10 Regional Partnerships that will:

- Competitively select RD&D projects for financial assistance based on technical merit and, generally, connecting innovators in their regions with RD&D funding;
- Provide analysis, data, access to federal RD&D facilities, and project management;
- Support development of early prototypes;
- Encourage and support collaborative RD&D, regional public-private partnerships, and consortia of innovative clean energy entities;
- Develop in collaboration with stakeholders regional energy innovation roadmaps to facilitate RD&D planning and inform annual plans submitted to DOE; and
- Coordinate with other Regional Partnerships on best practices and technology projects relevant to multiple regions.

B. Stakeholders

Mid-Atlantic Region State	Governor	Energy POC	Economic Development POC	Environmental POC
Delaware	Jack Markell	Dallas Winslow	Bernice Whaley	David Small
Kentucky	Matt Bevin	John "Rick" Bender	Erik Dunnigan	R. Bruce Scott
Maryland	Larry Hogan	Mary Beth Tung	Robert C. Brennan	Ben Grumbles
New Jersey	Chris Christie	Richard Mroz	Melissa Orsen	Bob Martin
Ohio	John Kasich	Asim Z. Haque	Jacqueline T. Williams	Craig W. Butler
Pennsylvania	Tom Wolf	Gladys M. Brown	Dennis M. Davin	Patrick McDonnell
West Virginia	Earl Ray Tomblin	Michael A. Albert	Keith Burdette	Randy C. Huffman

Table 1: State Stakeholders

Delaware:
Dallas Winslow (Chair, Public Service Commission)
Bernice Whaley (Cabinet Secretary, Economic Development Office)
David Small (Secretary, Department of Natural Resources and Environmental Control)

Kentucky:
John "Rick" Bender (Executive Advisor, Department for Energy Development and Independence)
Erik Dunnigan (Acting Secretary, Cabinet for Economic Development)
R. Bruce Scott (Commissioner, Department for Environmental Protection)

Maryland:
Mary Beth Tung (Director, Energy Administration)
Robert C. Brennan (Executive Director, Economic Development Cooperation)
Ben Grumbles (Secretary, Department of the Environment)

New Jersey:
Richard Mroz (President, Board of Public Utilities)
Melissa Orsen (Chief Executive Officer, Economic Development Authority)
Bob Martin (Commissioner, Department of Environmental Protection)

Ohio:
Asim Z. Haque (Chairman, Public Utilities Commission)
Jacqueline T. Williams (Director, Department of Commerce)
Craig W. Butler (Director, Environmental Protection Agency)

Pennsylvania:
Gladys M. Brown (Chairman, Public Utilities Commission)
Dennis M. Davin (Secretary of Community and Economic Development)
Patrick McDonnell (Acting Secretary of Environmental Protection)

West Virginia:
Michael A. Albert (Chairman, Public Service Commission)
Keith Burdette (Cabinet Secretary, Department of Commerce)
Randy C. Huffman (Cabinet Secretary, Department of Environmental Protection)

C. Agenda

Mid-Atlantic Region Energy Innovation Forum

Mid-Atlantic Region Energy Innovation Forum
Hosted by
West Virginia University
Morgantown, WV
September 12, 2016

WVU College of Law Event Center
101 Law School Drive
Morgantown, WV 26506

This Innovation Forum hosted by West Virginia University will bring together leaders from state government, academia and industry to discuss solutions and create a path for accelerating innovation in the Mid-Atlantic Region.

8:30 – 9:00 a.m.	**Registration and Networking**
9:00 – 9:05 a.m.	**Welcome** E. Gordon Gee President, West Virginia University
9:05 – 9:45 a.m.	**Panel 1: Regional Challenges and Opportunities** Moderator: Brian J. Anderson Director, Energy Institute West Virginia University Panelists: Grace Bochenek Director, National Energy Technology Laboratory U.S. Department of Energy Steven Winberg Program Manager, Battelle Andrew Gellman Co-Director, Wilton E. Scott Institute for Energy Innovation Carnegie Mellon University William Getty President, Claude Worthington Benedum Foundation Co-Chair, Power of 32
9:45 – 11:00 a.m.	**The Future of Clean Energy** Joe Manchin, III U.S. Senator, West Virginia David B. McKinley, P.E. U.S. Representative, West Virginia's 1st Congressional District Ernest J. Moniz U.S. Energy Secretary
11:00 – 11:15 a.m.	Break

11:15 – 11:45 a.m. **The Tri-State Governor's Regional Cooperation**
Chris Stadelman
Chief of Staff for the Governor, State of West Virginia

Dennis Davin
Secretary, Department of Community and Economic Development, Commonwealth of Pennsylvania

11:45 – 12:15 p.m. Lunch

12:15 – 1:15 p.m. **Panel 2: Innovation opportunities for fossil fuels in a future low carbon economy**
Moderator: Sean Plasynski
Executive Director, Technology Development & Integration Center, NETL

Panelists: James Bielenberg
Corporate Strategic Research, ExxonMobil Research and Engineering

Neeraj Gupta
Senior Research Leader, Battelle

Dave van der Wiel
Director, Babcock & Wilcox Research Center

David Zaziski
Vice President, Siluria

This panel will discuss the technical challenges and opportunities for innovation in the utilization of coal and gas. Recognizing the technical challenges associated from coal and gas utilization for electric power generation, this panel will focus comments on opportunities to significantly improve power generation processes, such as novel approaches to conversion and combustion via application of chemical looping and oxy-combustion technologies as well as the materials needed for ultra-supercritical steam conditions at coal-fired power plants. As these technologies still result in significant amounts of CO_2 emissions, CO_2 capture and storage innovation opportunities will also be discussed. Additionally, the potential for technology innovations in the utilization of natural gas will be explored. Topics will span new conversion pathways of natural gas and natural gas liquids. The development of shale gas resources in the region have spurred increased interest in new products, processes, and use of natural gas.

Mid-Atlantic Region Energy Innovation Forum

1:15 – 2:00 p.m. **Panel 3: Innovation opportunities in other clean energy technologies**
Moderator: Court Gould
Executive Director, Sustainable Pittsburgh

Panelists: Stewart Prager
Director, Princeton Plasma Physics Laboratory

Edward Herderick
GE Corporate Supply Chain and Operations

Denise Swink
Chair, Smart Manufacturing Leadership Coalition

This panel will discuss potential opportunities for identifying and creating new low-carbon pathways to drive economic growth in the region. Perspectives from both the creation of new, valuable products and from the creation of a nexus of innovation that creates and sustains itself on a critical mass of technical capabilities to serve both domestic and international markets. The potential for advances in manufacturing techniques to both raise the advantage of U.S. manufacturers to produce both conventional technologies as well as create the market advantage for those manufacturers to produce technology products of a specification not previously possible through traditional manufacturing techniques.

2:00 – 2:15 p.m. **Break**

2:15 – 3:15 p.m. **Panel 4: Policies Facilitating Sustainable Clean Energy Development**
Moderator: Scott Rotruck
Director of Energy & Transportation Services, Spilman Thomas & Battle

Panelists: Jan Mares
Senior Policy Advisor, Resources for the Future

Gary Helm
Lead Market Strategist, PJM Interconnection

Mike Casper
Senior Manager, Generation and Fuels, National Rural Electric Cooperative Association

3:15 – 4:00 p.m. **Panel 5: Regional Innovation Investment and Commercialization**
Moderator: Mike Green
Chairman, West Virginia Growth Investment Fund

Panelists: Jeffrey McDaniel
Executive-in-Residence, Innovation Works

Joseph Hezir
Chief Financial Officer, U.S. Department of Energy

Mark Nydam
Principal, HarbourVest Partners, Executive Chairman Accordant Energy

4:00 – 4:15 p.m. **Closing Remarks – Mission: Innovation**
Fred King
Vice President for Research, West Virginia University

D. General Session Notes

Welcome Session

Dr. E. Gordon Gee, West Virginia University

- WVU Energy Institute will forge relationships and create partnerships for economic growth.
- More than 150 university faculty members are currently researching environmental and energy issues, which includes an ongoing shale gas study being conducted in collaboration with the NETL.

Panel 1: Regional Challenges and Opportunities

Dr. Brian Anderson - Moderator (Director, WVU Energy Institute); Dr. Grace Bochenek (Director, NETL); Steven Winberg (Battelle); Andrew Gellman (Carnegie Mellon University); William Getty (Claude Worthington Benedum Foundation)

- **Overview by Dr. Brian Anderson**
  - Partnerships are key across all entities, including academia, nonprofit institutions, national laboratories, and industry.
  - Innovation is needed to continue the rich fossil energy history in this region.
- **Dr. Grace Bochenek**
  - This region is blessed with abundant resources including oil, coal, and natural gas. It is important that as the nation moves forward, utilization of these resources become part of the clean energy dialogue.
  - The Mid-Atlantic Region is at the epicenter of and is the driving force for energy research.
  - The Longview Power Plant features an advanced supercritical boiler and many advanced industry standards that are being employed globally. The Longview Power Plant features an advanced supercritical boiler, with R&D tied to NETL Clean Coal program.
  - Fracking has contributed immensely to the region and enhances our ability to compete globally in the natural gas marketplace.
  - Science, technology, and research are the anchors needed to meet the industry and economic challenges in our region.
  - Resources and research capacity form the foundation needed to address future challenges.
  - Natural resources (fossil fuels) satisfy 80% of energy requirements; substantial power generation includes fossil, nuclear, and renewable to power this region. Energy transmission is also very important to this region.
  - Government research facilities help convey fundamental research to industry for commercialization; this region has an abundance of experience in energy and will continue to innovate. Unconventional O&G is important to this region.
  - Goals can be achieved only via partnerships with all entities (government, industry, private, academic, etc.)
  - This region has top institutions with extensive energy experience and infrastructure (industry partners, academia, and national labs).
  - Advanced manufacturing enables the region to explore new ways of converting energy more efficiency.
  - Nontraditional and innovative uses of coal increase the full value of the coal resource.

- **Steven Winberg**
  - Eighty percent of coal is being burned in units over 30 years old. Plant age and environmental regulations make capital investments harder to justify. Virtually no new coal plants will be built over the next 10-15 years; therefore, coal consumption will decline by 50% by 2030 irrespective of CCP outcome.
  - Average age of our plants was 50 years old in 2015.
    - 2014 coal consumption = 849,000 M tons
    - 2015 coal consumption = 737,000 M tons
    - 2030 coal consumption = 550,000 M tons
  - Past technology commercialization models no longer work. The coal industry must take ownership for the next-generation of coal technologies.
  - Next generation coal technologies with Carbon Capture & Sequestration started at the National Energy Technology Laboratory. The region needs to proceed in a very aggressive manner. The coal industry can no longer rely on utilities to advance technologies. They have other less expensive options, have higher priority uses of their capital, and many have mandates to reduce coal consumption. The coal industry must partner with technology providers and build the pilot plants.
  - The issue with development is funding. The fuel, electric load, and land is available… everything except for funding.
  - Emissions can be reduced by reducing coal consumption. However, we must generate electricity somehow.
- **Andrew Gellman**
  - Opportunities for this region include converting natural gas into value added chemicals. This requires investment and not just the process and conversion.
  - Challenges –
    - Innovation starting from ground up requires incubator spaces. Energy technologies incubation requires hardware, which makes it much more challenging
    - Capital and venture capital not willing to invest in something that will not yield tens or even hundreds of times the investment paralleled with Silicon Valley.
    - Our region needs to encourage large institutions to invest time and interest in these small developing technologies
  - Challenges to innovation in this region:
    - Incubator Space: Innovation starting from the ground up requires space. Software innovation in our region is easy, but energy technology requires hardware and a testing process that is more challenging due to the region's limited space.
    - Capital and venture-capital: Hard to come by in this region; entities willing to invest in innovation with high-yields are much less abundant here.
    - Industry perspective: Industry believes that it is easier to market outside this region than inside; this is a simple problem that requires an organization to encourage and mentor smaller companies.

- **William Getty**
  - Governor's agreement among Ohio, WV, and PA to collaborate in natural gas and shale gas. This action plan is designed to maximize economic opportunity to attract downstream manufacturing. Value flows as you advance down the value chain; must use the product here (manufacturing). Governors understand we have a competitive research presence in physics, geology, chemistry, robotics, additive manufacturing, IT; important that these universities are collaborating around research. Access to R&D can be an attraction for businesses to do manufacturing because energy costs are down in this region and nationwide.
  - We have an advantage because we are reinventing the electric grid in this region and are in close proximity to an enormous marketplace. Transporting the finished product results in the highest cost and this region is within 700mi of 70% of North America's population.
  - The workforce in this region has owned up to what's missing; we must have a workforce development system that provides skills needed to obtain initial employment and keep moving up.
- **Question: What is the role of your sector across energy innovation? (Dr. Brian Anderson-WVU)**
  - **Dr. Grace Bochenek**: Our advanced computational and laboratory assets can help advance technologies toward commercialization. NETL has core capabilities that allow us to look at technology in its discovery state and help colleges and industry mature technology to commercialization.
  - **Steven Winberg**: Battelle offers contract research in an energy space that cuts across all forms of energy. They operate 6 national labs.
  - **Andrew Gellman**: Universities need to teach and create knowledge…they are good at creating new ideas and processes and can evaluate them for their economic impact. Universities are not biased; they can take concepts and fairly evaluate them for economic impact.
  - **William Getty**: Mediate, facilitate, and encourage collaboration. Foundation has an important role due to its non-profit nature.

The Future of Clean Energy

Joe Manchin, III (US Senator, WV); David McKinley (US House of Representatives, WV); Dr. Ernest J. Moniz (US Energy Sect.)

- **Joe Manchin**
  - Six counties in WV are experiencing a depression, and we need partners to help us move forward.
  - If we can accept climate change is causing an impact, then we can begin to create a path forward. Fossil energy is still in the mix until 2040 and will be a dominant driver for quite some time. The question is how do we use fossil energy better?
  - Can we use the plants we have and retrofit them to make them able to compete?
  - Concerns revolve around energy reliability, affordability, and availability in the region.
  - The region's coal miners are concerned about the inability to fulfill promises resulting from 1946 legislation promising that miners will receive benefits and pensions, which could affect 23,000 miners.

- Actively engaged in passing the Miner act - pension and health care and benefits are needed.
- Look at China: through 2040 there is a world coal consumption increase.
- India will become electrified in areas that have never had electricity before; they don't care how it is produced, etc.
- Question and uncertainty: Given that 7-8 billion tons of coal is being burned worldwide, if the U.S. stopped burning coal, would the rest of the world follow?
- Concerns: (1) reliability: Will affordable, reliable energy be abundant in the future? (2) We are investing in clean coal technologies, but the private sector has not stepped-up and will not until they have a certain/secure path forward.
- Tax credits for wind and solar should be instituted in areas in our state in which there is economic disparity. Would tax credits work? Looking for an incentive/cost to dial back into industry to help drive this region. Need to move tax credits to most affected areas.

- **David McKinley**
  - McKinley is 1 of 2 out of 535 members of Congress that are Professional Engineers, which makes the discussion of science and energy difficult.
  - What is the future of clean energy? It is whatever we want it to be. It does not have to only be renewables. Fossil fuels will be important part of the energy mix for the next 25 years at least. By 2040, 53% of the United States energy will be supported by fossil fuels. We need to figure out how to burn them cleanly and efficiently. We need the workhorse of coal and gas to be the base of the country's energy mix.
  - We must accept that fossil fuels are here to stay and must use them in a clean and efficient manner. We need to show China and India how to burn coal more cleanly.
  - The US's economy needs dependable energy, even though renewables are new and exciting.
  - Ignoring the clean aspects of coal has had an economic impact. Since 2008, 83,000 coal jobs have been lost in America. 73% of coal is being produced by U.S. companies that are in bankruptcy.
  - Other nations are not following our lead in energy efficiency. (Germany building 26 new coal-fired power plants, India doubling coal use in next 10 years).
  - MIT report states that it doesn't matter what the U.S. policy is on coal; as long as India continues to burn coal, we're still headed downward.
  - Japan and South Korea are building additional power plants. Japan committed to spending billions on advanced turbine research.
  - China is not performing research; they are learning by building (i.e., build one plant and learn from it, then build the next plant).
  - Longview Power Plant is the cleanest, most efficient power plant in the United States. Secretary Moniz is visiting later today.
  - To ensure that we lead in this research area, we must increase funding for NETL, for chemical looping, advanced combustion, rare earth element recovery, carbon capture, carbon sequestration and utilization. Need to increase funding for WVU and other research universities. We must examine ways to incentivize advanced power plant technologies. Congress should increase research funding into gas turbine facilities for combined and single cycle.

- Future of clean energy is bright, but we must be realistic regarding use of fossil fuels and should accept this challenge by leading (via NETL and the private sector) research to develop clean energy technology to show other countries how to burn coal more efficiently.

- **Dr. Ernest Moniz**
  - Regional focus of innovation is a key point of the discussion today. How do we structure the innovation for us to move forward?
  - Restructuring the budget has helped finance the NETL's transition to innovation of energy technology.
  - We are headed toward a lower carbon energy emission system, which does not mean getting rid of carbon fuels.
  - Regionally, there are challenges and opportunities, which is true for all regions when analyzed.
  - Innovation Agenda Items
    - Technology development: carbon capture, chemical looping.
    - How can we help transition the economy as we move toward clean energy?
    - Deep innovation needed for the de-carbonization that we will need in the century and beyond.
  - Oak Ridge and NETL need to think harder to combine a regional focus on energy innovation and what that might mean in the area.
  - Regional Theme of Innovation is very important and will impact how we structure innovation moving forward. NETL and FE have worked this year to restructure the budget to allow for fertile growth. This is an important step for the future of NETL.
  - Important to build NETL capability in fossil fuel research. We need a lead lab for fossil energy.
  - (1) Lower carbon emissions do not mean discontinuing the use of fossil fuels.
  - 1.3 trillion cubic feet of natural gas production in West Virginia.
  - Transformation will occur over decades: We need to stay ahead in the innovation game and capture a piece of this market.
  - Technology development and what we can do? Coal sector strongly impacted in this region. The principal driver of low cost of coal for electricity is not regulation but the low cost of natural gas. Enormous production of low-cost natural gas has created a natural gas revolution.
  - If you are a utility, diversification makes a big difference in a portfolio. Coal utilization with carbon capture needs signals now, need signals to allow sound investment decisions.
  - What can we do/not do working with regions/states to help transition the economy and jobs? DOE has focused on jobs and strategy.
  - Innovation agenda: deep innovation needed in the mid-century and beyond
  - Crosscutting activities that are relevant to these challenges: advanced materials, led by fossil energy critical cycles; advanced energy system program (fuel cell, supercritical CO2 cycles)
  - FY17 request includes funding for carbon sequestration partnerships.
  - Deployment side projects being evaluated.
  - FOCUS ON ONE THING!!!! important in near term: TAX CREDITS! Administration has for the last two years proposed building plants and storing CO2. Similar initiative called for tax

credits; very important to get this done. Hope that this year Congress can succeed in getting tax credits across the finish line. This is important because CCS plants are not going to be operating for 10 years (that will not address today's problems). This may be true, BUT the signal today is critical because utilities base their projections on 10-year timescales. If I'm the risk officer at a utility, today capital costs for natural gas plants and fuel costs are low, but what is my risk profile if I'm exposed to fuel cost volatility?
        - This is why it's so important now to do this!!!
    - Iowa has the highest fraction of wind production in the nation (20%) and increasing... Governor and the industry said one of the reasons they have built capacity in Iowa is because of the options value of direct source costing of wind.
    - ECONOMY/JOBS/TRANSITIONS: DOE proposed up to 10 regional-clean energy partnerships. Proposed an increase in innovation budget, sustained over 5 years, in this DOE proposed $110M in regional partnerships. This funding would go to nonprofits to manage partnerships for clean energy in each region. Each region will have its own unique portfolio. DOE will be soliciting ideas to structure the process.
    - LOOK TOWARD LONG-TERM FUTURE...we need to invest in big game changers that could have enormous impact on ways coal can be used in low carbon environments. For example; CO2 + water + sunlight could replace hydrocarbons for fuel.
    - Working across WV for automotive supply chain to increase jobs.
    - DOE's job strategy council works with labor and other groups and is committed to a joint effort with a multitude of entities to impact policies.
    - Bill Gates is pioneering 20-year return, risk tolerant investments for the few technologies that have a big material impact because of Mission Innovation. Need everyone's help to accomplish this.
- **Question 1: What interplay would you like to see between electric vehicles and coal power plants? (WVU Student)**
    - **Dr. Ernest Moniz:** If one looks at any scenario for low carbon agenda, the electricity sector decarbonizes the fastest. The International Energy Agency indicates that CC&S is very important. Electrification of vehicles will help, but will come more slowly. Three ways to reduce carbon: electrification, higher efficiency vehicles (better MPG, aerodynamics, etc.), and alternate fuels (liquid, fuel cell, biofuels, etc., but in longer term will include dropping fuels)
- **Question 2: Could the deadline for power plants be extended? Would the Administration be open to extending the timeline for the CCP to allow for more investment? To promote more confidence?**
    - **Dr. Ernest Moniz**: tax credits this year would be a big deal. A trajectory for carbon reductions is needed by the investment community.
    - **David McKinley:** timeline needs to be extended. FERC (Steve Mollar) testified that coal-fired power plants need to be updated or there will be brownouts. Should use existing facilities to meet current needs. We need a time extension to be able to use what we have. We need time to retrofit these facilities. NETL developed technology to retrofit existing facilities, but we need time to adapt these processes. Even old plants can be retrofitted.

- **Joe Manchin:** Need technology in place; nobody has factored in economic impact of a decrease in coal production for this region. No one is factoring in the economic impact on southern WV, KT.

The Tri-State Governor's Regional Cooperation

Chris Stadelman (Chief of Staff, WV Governor); Dennis Davin (Sect., Dept. of Community and Economic Development, PA)

- **Chris Stadelman**
  - Tomblin believes innovation is a key. Coal needs to be a large part of our energy needs along with shale.
  - Development of natural gas fields are still in their infancy and continue to provide new opportunities.
  - Three-pronged approach
    - Drug free and educated workforce.
    - Real opportunity comes from downstream development.
    - Pipeline development and infrastructure.
  - GOV Tomblin believes that energy innovation is an integral to WV future
  - Working on shale gas, Marcellus and Utica. Working groups to address research, marketing, etc. for shale gas. Working with partners to determine how to move forward. Branding strategy, storage, transport, and others for gas produced here.
  - Opportunities started with coal, but none are like shale gas; could be a huge game changer in this region. WV first state to pass crosscutting legislation for companies to extract gas.
  - Drug free and educated workforce is key to creating a strong energy environment.
  - Extraction of gas is important, but downstream development is very important as well. Natural Gas Crackers could be coming to Wood county and others, and all 3 crackers can benefit all 3 states.
  - Need to recognize and brand the Appalachian basin and region to compete with the gulf coast.
- **Dennis Davin**
  - Pennsylvania has pursued an aggressive economic development policy. The abundance of natural gas in southern Pennsylvania gives them a distinct advantage for development.
  - A partnership with Consol to drill on airport land was one of the most important partnerships. It has injected millions of dollars back into the airport for upgrades and top staff.
  - Ten billion in infrastructure for natural gas pipelines and infrastructure and countless businesses are in the queue.
  - Proctor and Gamble has an advantage because they own the gas and mineral rights, which they use to gain a competitive advantage over their competitors through low cost energy for their manufacturing facility.
  - Shell building cracker plant in Beaver County that will benefit the entire region.
  - Relying on one industry to support an entire economy can result in significant impact when it collapses; must diversify and increase jobs in other areas to sustain the economy.
  - Collaborating with WV and Ohio for a tri-state Shale Gas industry, must get natural gas to market. Many wells are shut in due to lack of pipeline infrastructure. Must build a world-class pipeline infrastructure and do it the right way; development of NG industry relies on key factors. Must develop infrastructure now to enable companies to benefit.

- Need to work with industry and universities to innovate and establish a ready workforce. Need to address challenges with coal industry, but may give an opportunity for NG production.
- PA looking at utilizing NG for benefit of PA.

- **Questions:**
  - Why has the Governor focused on shale gas instead of all of the above strategies in all energy?
    - **Chris Stadelman answer:** New opportunity as shale was the focus for our office, currently looking at other opportunities (wind, etc.).
    - **Dennis Davin answer:** diversified economy and energy sources for PA.
  - Low carbon energy space, comment on what roles states can play in advancing low carbon energy in each state.
  - **Answer PA:** Regulatory department playing big role in low carbon; Department funding sources being utilized; looking at opportunities for wind and solar projects with funding sources.
  - **Answer WV:** WV has a number of wind mill sites, which can be controversial. There is a CCS pilot plant in Texas and need them in WV and throughout the region. The Governor is focused on innovation in WV.

Panel 2: Innovation opportunities for fossil fuels in a future low carbon economy.

Sean Plasynski-Moderator (TDIC, NETL); James Bielenberg (ExxonMobil); Neeraj Gupta (Battelle); Dave van der Wiel (Babcock & Wilcox Research Center); David Zaziski (Siluria)

- **Dave van der Wiel:**
  - "Coal will be an important fuel internationally and domestically for a long period of time."
  - In the absence of market drivers, continued federal support of clean coal R&D is critical
    - Incentives to replace existing coal with Ultra-supercritical coal combustion instead of only Natural Gas
    - Emphasis on adoption of technologies
    - Agree with CURC CCS technology roadmap; public-private cost share model
  - Adoption of CCS technologies will require successful large-scale integration demonstrations
    - CCS technologies are still too immature for full commercialization.
    - Corporate investments are not possible without a near-term market beyond Enhanced Oil Recovery
  - Oxy-Combustion Technology
    - Chemical looping technology is promising and progressing well.
    - High-temperature USC materials expertise feeds directly to sCO_2 cycles.
  - CO_2 capture technology
    - Membrane processes are technically and financially attractive and are transferrable to many applications/markets.
  - Natural gas utilization
    - Advances in coal chemical looping transfer directly to natural gas conversion.
    - Greenhouse release of methane needs to stop being ignored
    - Burning NG wastes its chemical potential
  - B&W, NETL, U.S. DOE, The Ohio State University, and the Ohio Development Services Agency are collaborating on a 250 kW pilot plant program at B&W Research Center.
  - B&W, Membrane Technology Research and U.S. DOE are collaborating on an integrated pilot test project for CO_2 Membrane separation at 1MW.

- **James Bielenberg:**
  - Two obvious areas: de-carbonization with methane and NG conversion to other products.
  - Three main points:
    - Real possibility by moving gas up the value chain
    - There are technology options to do this; it is not impossible to turn methane into other products
    - Areas to create innovations to make this happen
  - Where gas is today: Gas is limited in end use, mainly used in power generation, (about 90% of methane is used for this). Can add components to gas; use it in a multitude of ways.
  - Four key challenges to methane conversion
    - non-oxidative coupling: Problem is it's very hot, hard to get there
    - Oxidative Coupling: Kinetic problem of stopping reaction partway through
    - Low-temp direct Oxidation: Complicated, difficult to find systems that work and make them relevant
    - Conversion via Syngas: Works well, but costs a lot.
  - "At ExxonMobil we are keenly aware of the technology-rich nature of our business. Technology is the very lifeblood of our success today and it is the platform for our success tomorrow." –Rex TIllerson, CEO EM corp.
  - Three areas of methane R&D:
    - Materials and process concepts for light molecule separation
    - Theoretical and experimental scoping of catalytic materials
    - Advanced concepts in reactor engineering and process intensification
- **David Zaziski:**
  - One conversion method: Oxidative Coupling for methane conversion
  - Petrochemicals vs. liquid fuels
    - Economies of scale produce world-scale facilities that cost many billions to construct and only a couple companies can finance these; also see a clustering of these large facilities (U.S. Gulf Coast)
  - How can you utilize (NG) to get other useful products?
  - Breakthrough catalytic process
    - World's largest building block for petrochemicals
    - Cleaner liquid fuels
  - Siluria's innovative chemistries
    - CH_4+air, enriched air, or O_2=> Ethylene + H_2O
    - Siluria developed a catalyst that performs this process and has economically viable uses.
  - Integrated pilot operations
    - Dow and Aramco have worked on this reaction, but Siluria was successful. Talked to many people in the field to determine why things worked and did not work. Incorporated nanomaterials and tested.
  - Made over 90k options, found a few catalysts that performed under the conditions needed to be commercially viable.
  - Have a demonstration plant in La Porte, TX for this process. Methane in, ethylene out.
  - OCM does/is:
    - Provides a pathway to produce ethylene from NG
    - Produces ethylene on a large scale
    - Only direct (non-syngas) pathway from NG to fuels

- **Neeraj Gupta:**
  - The Midwest Regional Carbon Storage Partnership consists of 10 states in partnership and includes members from geology companies, universities, and other industries. Work on the Phase III MRCSP partnerships is ongoing.
  - Several projects with Carbon Storage
    - MRCSP Leadership
    - AEP mountaineer geologic storage
    - Geologic storage for FutureGen
    - Assessment of wellbore integrity
    - Simplified modeling for CO_2 storage
    - Mid-Atlantic U.S. offshore CO_2 Storage
    - CO_2 geologic storage in the ARCHES province
    - Developing CO_2 Storage options in Ohio
    - Improved recovery for small producers in Ohio
    - Brine disposal potential in the Appalachian Basin
    - Geomechanical framework for fluid injection
    - Exporting technology
      - China, Mexico, South Africa, Japan all working with Battelle
  - Building a map across 10 states for potential CO_2 Storage sites.
    - State geological surveys are utilized
  - Characterization work with NG and Brine industries to identify new storage horizons
  - CO_2 utilization in Ohio oilfields is of interest.
  - **Question: Question: Worried we're putting too many eggs in CO_2 capture basket, (nanotech, etc.) any work beyond CO_2 capture?**
    - Exxon interested in different possibilities, but in looking at the size of the power market, it is hard to justify backing away from power generation. Hard to develop a whole new technology if it's a niche product.
  - **David: different stages of innovation cycle funding**
    - Raised over $170M in investment capital; big investment unmatched from venture investors. Regulatory side: tactically build where permitting is easier. During scale up, any gap is traumatic to the organization.

Innovation Opportunities in other Clean Energy Technologies

Court Gould-Moderator (Sustainable Pittsburgh); Stewart Prager (Plasma Physics Laboratory); Dr. Edward Herderick (GE Corporate Supply Chain and Operations); Denise Swink (Smart Manufacturing Leadership Coalition)

- **Denise Swink**
  - Opportunities to invigorate a better supply chain
  - Manufacturing challenges and innovation approaches on the enterprise level.
  - Organization infuses more intelligence in manufacturing
    - Majority of manufacturing is still not technologically sound, need to increase focus.
    - Group of companies has collaborated to build a prototype for a smart manufacturing database of hardware and software to solve manufacturing problems while creating a lively marketplace.
    - Pay for what you need when you need it, not locked into one technology, grow where you want to. Eliminates non-integration in a plant. Cloud-based platform to knit together these things.
    - Energy perspective: Most manufacturing designed to an energy efficiency level only after the utility bills are paid. Give them the tools and capabilities that drive down the risk of trying new technology.
- **Stewart Prager**
  - Fusion is a global enterprise at the moment. Sale of fusion reactors is a long way off, but will be a truly transformative carbon safe energy. Fusion is completely devoid of greenhouse gasses (GHGs). The industry is not there yet because fusion is very difficult and funding has never been enough to build the test beds needed.
  - Special moment for fusion energy
    - ITER facility (operational in 10 years) in south of France (international collaboration). Will generate 500MW of fusion for 8 min at a time. No energy on the grid, but just testing many of the technologies for fusion. US a 9% partner, $4-5B being spent in U.S. fabricating components.
  - Challenges remain:
    - Scientific challenges of plasma control, sustainability
    - Technological challenges: surround plasma with material for long period of time. Additive manufacturing will have big impact.
  - Who is supporting Fusion?
    - U.S. Russia, other governments supporting fusion research; private sector investment in last decade.
- **Dr. Edward Herderick**
  - Digital industrial revolution, ties from WVU and GE
  - Industrial revolution between IT and physical assets and how additive manufacturing fits into place.
  - Opportunity for all industry in WV region for manufacturing and supply chain.
  - Brilliant factory
    - Driven by digital thread; software tied to everything; AI and machine learning at the core.
  - Digital analytics for managing assets
    - New elements for software and digital analytics to drive efficiency across all power plants
    - Monitoring, focusing on uptime, in-situ monitoring and maintenance of power plants
    - This region can build on current expertise to innovate on a global scale.

- Huge opportunities in additive manufacturing

- **Michael N. Worley**
  - Nuclear energy issues are time, cost, etc.
    - RD&D requires lots of time and expense; small venture capital companies will not invest.
    - National Labs have capabilities, but no way to convey these capabilities
  - Plant design and licensing of nuclear power plants is slow right now
  - Making available nuclear capabilities, computational capabilities, and modeling and simulation tools.
  - Initiated a pilot voucher system to make funds available
  - Small startup firms don't have the resources to invest in a large undertaking such as nuclear energy.
  - Partnering with EPRI for powdered metal and other additive manufacturing
    - Could make nuclear energy a viable option if costs are decreased.
- **Questions:**
  - **Brian -** Fusion energy sciences ongoing at WVU, moved fusion reactor to campus; materials science transcends fuel type and is being explored heavily in this region.
  - What are some of the other crosscutting technologies and challenges in additive manufacturing for developing materials able to withstand harsh environments?
    - GE: additive manufacturing includes many different technologies (i.e., making tooling, casting/welding, etc.) investigation into how we use this to casting base; two challenges:
      - Making larger castings
      - Replace castings/forgings with welds, not a show stopper but is difficult.
  - Connecting innovation in learning: How do you connect ongoing research to education?
    - Denise: Companion workforce stream, curriculum development and research. Shell is a member and is working in the Gulf Coast to develop a pilot test facility for training and experimentation.

Panel 4: Policies Facilitating Sustainable Clean Energy Development

Scott Rotruck-Moderator (Spilman Thomas & Battle); Jan Mares (Resources for the Future); Gary Helm (PJM Interconnection); Mike Casper (National Rural Electric Cooperative Association)

- **Jan Mares**
  - Citizens, For-Profit and Non-Profit organizations, and Government can facilitate clean energy development.
  - Clean energy development needs policies that facilitate:
    - Support for public and private sector efforts to inform public about potential threats from and means of addressing climate change
    - Research to determine extent of effectiveness of 'clean energy' technologies and energy efficiency policies as a means of making them more effective
    - Continued federal support for "clean energy" R&D
    - Federal government can provide tax incentives for CCS
    - Continued efforts to promote energy efficiency including regulation
    - Training people for new occupations
    - Increasing the price of carbon emissions, which will drive changes in business activities and investments in low-carbon manufacturing goods and services
    - Early adoption of clean energy technologies and services by government.
- **Gary Helm**
  - PJM Interconnection operates high voltage grid in this region.

  - Shale gas has changed economics of PJM dramatically.
    - Make sure there are enough resources three years in advance
    - Coal production decreased after early 2015, with oil and gas expected to increase drastically.
    - Other technologies will be coming online if economically viable, but 80% of market additions since 2007 have been Gas.
    - Overall, coal is down and natural gas, nuclear, and renewables are up.
- **Mike Casper**
  - Rural areas comprise 11% of power consumption, but they are an integral part of energy generation.
  - Changed landscape from 2015 to 2016
    - Extension of ITC/PTC: 20-25% increase in renewables
    - Low natural gas prices: expected to remain in $3-5 range or less
      - Impacts on coal: generation 17% lower over 2016-2040 period
  - Strategic solutions:
    - Keeping fossil generation in the game:
      - Carbon utilization
      - Local generation
    - Environmentally beneficial electrification
      - Increased efficiency
      - Declining carbon intensity of electricity
  - Local Generation Value
    - Developing local options (solar, other)
  - The "Community Storage Initiative"-Beneficial Electrification
    - Electric water heater: incentive free water heater, discounted community solar panels
    - Electric vehicle: incentive free wind power upgrade, discounted charging station
    - Tesla Powerwall
  - Heath Dennis spoke on Carbon Reduction
    - Increased efficiency of electric utilities (heat pumps, etc.)
    - Declining CO_2 intensity, less coal, more natural gas, nuclear, renewables to meet carbon reduction targets by 2030.
  - Frequency and Voltage research solutions
  - Grid Ballast Project: ARPA-E project
    - Electronic device to help create autonomous frequency regulation to respond in real-time without communications and built into consumer electronics.
- Natural gas could be the next coal just as coal was in the past. Don't prematurely write off energy sources. Innovation means thinking outside of the box; with the right amount of innovation this can be a game changer
- Carey Butler:
  - Must have economic indicators to direct market, others contradicting this.
  - John Mares: Elected officials are not going to talk about this; there is much discussion on both sides, but much more discussion now than before President Obama was elected. This will be a big issue if Hillary Clinton is elected. There is a lot of discussion underway on many aspects of a tax incentive. RFF funded to put together five models any questions concerning Carbon impacts on the economy.
- Debbie: two questions:

- Carbon taxes do not work based on current examples, what do you think of this?
  - B.C.s has worked well, but view of effectiveness is based on what has happened in the world (mixed views).
- What do you think the percentage of renewables will be by 2020-2025
  - Mike: NERL study showing that up to 30% renewables by 2030 interconnected in the east (of Mississippi river); a lot of money needs to be spent on transmission for this to happen, it will take time.
  - Gary: Renewables are progressing, but we are not going to be overwhelmed. Will still have lots of nuclear energy and natural gas going forward; not going to be destructive.
- Investment tax credit for coal vs. renewables.
  - Gary: needs to be competitive, and must have CCS, so tax credit still not going to be enough.
- Kelly P: regional competitiveness, job creation, and transitioning appropriately, any issues with private investors without federal carbon policy?
  - John: Risk in every business; there is no greater risk of having a price on carbon vs. not, but research based is a better way to address a very important issue
- Impact of structural change on coal workers and how renewables will replace them. Salaries in renewables vs. coal, how this may happen.
  - John: jobs in this area with petrochemicals could be huge.
  - Gary: Don't look at job economics, just focus on reliability. Employment levels at plant vs. mining are large, but no comment really.
  - Scott: Need to find some way to train displaced workers to make them productive again.

Panel 5: Regional Innovation Investment and Commercialization

Mike Green-Moderator (WV Growth Investment Fund); Jeffrey McDaniel (Innovation Works); Joseph Hezir (CFO, DOE); Mark Nydam (Accordant Energy)

- **Mike Green**
  - Very little venture capitalism in this region
- **Jeffery McDaniel**
  - Model to think about, Innovation Works.
  - An early, state seed investor; identify startups and concepts that are right for investment and help them cross some boundaries
  - Part of the Ben Franklin technology partnership
  - Non-profit, but do focus on energy and manufacturing and model the for-profit venture space instead of a more traditional stance. We want to make sure that companies get a head start on thinking how they will progress.
  - In addition, we have Acceleration Programs that have evolved over time. Ben Franklin Technology Partners located throughout PA evolved to better accommodate the region. These organizations help address the lack of venture capital in this region. Limited to investments in PA, but unlimited in their nine county swath.
  - All of the above approach from energy and portfolio perspectives
  - Good news is pipeline continues to grow, bad news is that you've got a growing pipeline of good ideas without enough capital to motivate it.

        - Key take aways: partnering (public and private); access to resources means more than just capital, it means providing test beds to prove concepts. Regional Development is also important; most starter companies will make it by selling their products in a region other than this. Finally, we all can help the U.S. increase its energy IQ. The investment community needs to increase its IQ, and we all need to work on educating the workforce to understand the impacts energy has on all of us.
- **Joseph Hezir**
    - Presentation focused on several areas
    - Two commercialization incentives: CCUS Tax credit and loan guarantees.
    - Commercialization is both an outcome and driver of the innovation process
    - Future of NG study; lots of research after regulations in 1970s, moved to private sector with GRI Funding steady over 16 years, implemented a time limited tax credit. Production under this tax credit is slow but steady. Once all the technologies came together, NG production boomed.
    - CCUS tax credit issue:
        - New Investment Tax Credit (ITC), 30% of the installed cost of the eligible property, new or retrofitted electric generating units; eligible property includes carbon capture tech with CO transportation and storage infrastructure (pipeline, wells, and monitoring systems), $2B cap, credit if refundable
    - Expanded Sequestration Tax credit (STC)
        - $10 per metric ton for CO2 that is beneficially reused; $50 per metric ton for CO_2 that is not beneficially reused (geologic storage, etc.)
    - How tax incentives have significant leverage
        - ITC lowers up-front investment in CCUS by 30%; STC results in $3.8/MWh cost savings for every $10/ton of carbon sequestered
    - DOE modeling analysis found significant commercial market potential
        - Modeling can incentivize 30 GW of coal and NG CCUS by 2030 and up to 50 GW by 2040.
        - Also provides options for CO_2; beneficial use vs. non-beneficial use depends on relative difference between the levels of both STCs.
    - DOE Credit authority available for a wide range of innovative technologies.
        - $40B in
            - Advanced vehicle technologies
            - Advanced Fossil energy
            - Renewable energy
            - Advanced nuclear energy
- **Mark Nydam**
    - Diversifying and revitalizing regional rural-based partnerships
    - Challenges for regional rural based economies
    - Regional income dependency
    - Regional imbalance in export GDP ratios
    - Community by community competition
    - Resource extraction focus
    - Adverse impacts on regulatory changes
    - Basic community focus – no value added
    - Declining labor participation

- Industry cluster approach identifies the competitive segments of an economy that can drive economic diversification and revitalization. Examples for this region include:
  - Coal
  - Technology
  - Manufacturing
  - Agriculture
  - Tourism
  - Timber
- Use the Porter Diamond/SWOR Analysis and get a roadmap for diversification
- Successful application in a rural area creates certain challenges:
  - Larger geographies mean more upfront effort identifying and facilitating collaboration.
  - Rural collaboration is difficult due to more traditional views; need to understand that economic success is not a zero-sum game.
  - Local leaders meet to identify opportunities and drive changes; need to lead the effort to overcome "victim mentality".
- Regional Approach Components:
  - Financing Facility
  - Economic Development Plan
  - Business Incubator Networks
- Benefits of this approach are:
  - Approached from a practical business standpoint that makes economic sense and drives economic benefits

- Question: Tie some things together; commercialization in the region, diversification, and demand-side push and pull in the region.
  - Joseph: shale gas utilization is one driver, but CCS and Carbon Management could form a cluster. The supply chain is one area that was discussed very little. An opportunity exists that could help drive growth in this area.
  - Jeffery: Cluster concept is a very good one, but the cluster is energy as a whole instead of one technology. We have some of just about every technology in these 32 counties here.
  - Mark: Services could be interesting too, and provide good paying jobs.

E. Regional University Stakeholders

Institution	Public/Private	City	State	Carnegie Classification
Carnegie Mellon University	Private	Pittsburgh	PA	R1
Case Western Reserve University	Private	Cleveland	OH	R1
George Mason University	Public	Fairfax	VA	R1
George Washington University	Private	Washington	DC	R1
Georgetown University	Private	Washington	DC	R1
Johns Hopkins University	Private	Baltimore	MD	R1
Ohio State University	Public	Columbus	OH	R1
Pennsylvania State University-Main Campus	Public	University Park	PA	R1
Princeton University	Private	Princeton	NJ	R1
Rutgers University-New Brunswick	Public	New Brunswick	NJ	R1
Temple University	Public	Philadelphia	PA	R1
University of Cincinnati-Main Campus	Public	Cincinnati	OH	R1
University of Delaware	Public	Newark	DE	R1
University of Kentucky	Public	Lexington	KY	R1
University of Louisville	Public	Louisville	KY	R1
University of Maryland-College Park	Public	College Park	MD	R1
University of Pennsylvania	Private	Philadelphia	PA	R1
University of Pittsburgh-Pittsburgh Campus	Public	Pittsburgh	PA	R1
University of Virginia-Main Campus	Public	Charlottesville	VA	R1
Virginia Commonwealth University	Public	Richmond	VA	R1
Virginia Polytechnic Institute and State University	Public	Blacksburg	VA	R1
West Virginia University	Public	Morgantown	WV	R1
American University	Private	Washington	DC	R2
Bowling Green State University-Main Campus	Public	Bowling Green	OH	R2
Catholic University of America	Private	Washington	DC	R2
Cleveland State University	Public	Cleveland	OH	R2
College of William and Mary	Public	Williamsburg	VA	R2
Drexel University	Private	Philadelphia	PA	R2
Duquesne University	Private	Pittsburgh	PA	R2
Howard University	Private	Washington	DC	R2
Kent State University at Kent	Public	Kent	OH	R2
Lehigh University	Private	Bethlehem	PA	R2
Miami University-Oxford	Public	Oxford	OH	R2
New Jersey Institute of Technology	Public	Newark	NJ	R2
Ohio University-Main Campus	Public	Athens	OH	R2
Old Dominion University	Public	Norfolk	VA	R2
Rutgers University-Newark	Public	Newark	NJ	R2
Stevens Institute of Technology	Private	Hoboken	NJ	R2
University of Akron Main Campus	Public	Akron	OH	R2
University of Dayton	Private	Dayton	OH	R2
University of Maryland-Baltimore County	Public	Baltimore	MD	R2
University of Toledo	Public	Toledo	OH	R2

F. Attendee List

Last Name	First Name	Company/Organization
Abramson	Alexis	Case Western Reserve University
Adams	John	WVU Energy Institute
Anderson	Brian	West Virginia University
Anderson	Dianne	Anderson Energy
Bajura	Richard	West Virginia University
Baker	Chelsea	
Barth	Anne	TechConnect West Virginia
Beard	David	Post
Bentzel	Suzanne	West Virginia University
Bielenberg	Jim	ExxonMobil Research & Engineering
Blankenship	George	First Energy
Bochenek, Ph.D.	Grace	U. S. Department of Energy, National Energy Technology Laboratory
Boechler	Andrew	GE Oil and Gas
Boggs	Mara	Office of U.S. Senator Joe Manchin
Bolt	John	WVU News Services -media
Brickett	Lynn	USDOE- National Energy Technology Laboratory
Butler	Carey	KeyLogic Systems, Inc.
Caputo	Mike	WV House of Delegates
Casper	Mike	National Rural Electric Cooperative Association
Challman	Don	University of Kentucky Center for Applied Energy Research
Cilento	Gene	WVU Statler College
Clutter	Greg	MATRIC
Cohen	Jed	Division of Economics and Management
Cokeley	Hampton	U.S. Senator Shelley Moore Capito
Cole	David	The Ohio State University
Davin	Dennis	Department of Community and Economic Development
Dennison	Cory	Vision Shared
Deskins	John	WVU College of Business and Economics
Dewitt	Gabe	
DiGregorio	Kevin	Chemical Alliance Zone
Ditmore	Mary	West Virginia University
Dorsey	Mark	AFL CIO
Doyle	Dan	NETL
Dunaway	Gregory	West Virginia University
Erickson	Mary E.	
Esselman	Tom	LPI, Inc.
Ferrell	Mark	EPA Region 3

Last Name	First Name	Company/Organization
Fershee	Joshua	West Virginia University College of Law
Forde	Steve	XTO Energy
Foster	David	U.S. Department of Energy
Francis	Chad	UMWA
Fulay	Pradeep	WVU Statler College
Gee	Gordon	West Virginia University
Gellman	Andrew	Carnegie Melon University
Getty	Pat	Benedum Foundation
Gould	Court	Sustainable Pittsburgh
Green	Michael	West Virginia Growth Investment Fund
Greza	Lucas	
Gupta	Neeraj	Battelle
Hammock	Jon	KeyLogic Systems, Inc.
Harbaugh	Matt	Office of Transformation
Helm	Gary	PJM Interconnection
Herderick	Ed	GE Corporate Supply Chain and Operations
Herholdt	Jeff	West Virginia Division of Energy
Hezir	Joseph	HQ DOE
Hill	Brian	Richard King Mellon Foundation
Hindman	John	Leidos
Ho	Jacqueline	Resources for the Future
Hohn	Michael	West Virginia Geological Survey
Hu	John	WVU
Jarrell	Joshua	West Virginia Department of Commerce
Junkins	Casey	The Review Wheeling, WV
Kelly	Katrina	University of Pittsburgh, Centre for Energy
King	Chris	U.S. Department of Energy
King	Fred	West Virginia University Research Office
Koepke	Mark	WVU -Physics
Lakatos	Margie	U.S. Department of Energy, National Energy Technology Laboratory
Lane	Annie	Battelle
Liu	Xingbo	West Virginia University
Manchin	Joe	U.S. Senator
Mares	Jan	Resources for the Future
Mattise	Jonathan	Associated Press
McDaniel	Jeffrey	Innovation Works
McKinley, P.E.	David B.	U.S. Representative
Meagan	Yachini	
Miller	Bob	
Moniz	Ernest	U.S. Secretary of Energy

Last Name	First Name	Company/Organization
Morreale	Bryan	national energy technology laboratory
Murphy	Sheena	WVURC
Nuzum	Clinton	
Nydam	Mark	Accordant Energy
Osborne	Rod	Battelle
Peduto	Guy	INNOVA Commercialization Group
Plasynski	Sean	U.S. Department of Energy - National Energy Technology Laboratory
Prager	Stewart	Princeton Plasma Physics Laboratory
Ramsey	John	KeyLogic Systems
Raney	Bill	West Virginia Coal Association
Rasar	Kimberly	
Riivald	Marje	WVUEI
Robison	Daniel	WVU - Davis College of Agric, Nat Resources and Design
Rotruck	Scott	Spilman's Thomas & Battle
Runyon	Sam	Senator Joe Manchin III (D-WV)
Sanjaya	Dr	West Virginia State University Energy and Environmental Science Institute
Sell	Jessica	Fairmont State Foundation
Shaffer	Budd	Deloitte
Stadelman	Chris	Office of Gov. Earl Ray Tomblin, West Virginia (Sherri is Mr. Stadelman's admin)
Stine	Deborah	Carnegie Mellon University Scott Institute for Energy Innovation
Stores	Katie	WVU, Eberly College, Office of the Dean
Swink	Denise	Smart Manufacturing Leadership Coalition
Taylor	Samuel	WVU Energy Institute
van der Wiel	David	Babcock & Wilcox Research Center
Van Nostrand	James	WVU College of Law Center for Energy and Sustainable Development
Venuto	Sarah	Senator Joe Manchin III (D-WV)
Veser	Goetz	University of Pittsburgh
Vu	Cung	Case Western Reserve University - Chevron (Retired)
Wafle	Trina	WVU National Research Center for Coal and Energy
Webb	Erik	Sandia National Labs
Wheatley	Beth	The Nature Conservancy
Wheeler	Sarah	West Virginia University
Wilson	James	National Energy Technology Laboratory (DOE)
Winberg	Steven	Battelle Memorial Institute
Wood	Farley	Tetra Tech Inc.
Wood	James	West Virginia University
Worley	Michael	U.S. Department of Energy
Zapinski	Ken	Allegheny Conference on Community Development
Zaziski	David	Siluria Technologies, Inc.
Ziemkiewicz	Paul	Water Research Institute

G. Panelist Bios

Mid-Atlantic Region Energy Innovation Forum

Hosted by
West Virginia University
Morgantown, WV
September 12, 2016

WVU College of Law Event Center
101 Law School Drive
Morgantown, WV 26506

Supplementary Materials

Biosketches

Dr. Brian Anderson

Directory, WVU Energy Institute
West Virginia University

Brian J. Anderson is the GE Plastics Materials Engineering Professor in chemical engineering at West Virginia University (WVU).

He was awarded the 2012 Presidential Early Career Awards for Scientists and Engineers, the highest honor bestowed by the U.S. government on science and engineering professionals in the early stages of their independent research careers. He has been a NETL-RUA Faculty Fellow at the National Energy Technology Laboratory since 2008 where he is the coordinator of the International Methane Hydrate Reservoir Simulator Code Comparison study. Dr. Anderson received his Bachelor's degree in chemical engineering in 2000 at WVU and his MS and PhD in chemical engineering from the Massachusetts Institute of Technology in 2004 and 2005 respectively.

After joining the faculty at WVU in January of 2006, he coauthored the MIT report, "The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century," considered the seminal report on EGS and the future of geothermal energy. He was awarded the College of Engineering and Mineral Resources New Researcher of the Year in 2007. In 2010, Dr. Anderson was selected to the National Academy of Science's 2010 Frontiers of Engineering Education Workshop, named the College of Engineering and Mineral Resources Teacher of the Year, and was the Opening Keynote speaker at the inaugural 2010 Gordon Research Conference on Gas Hydrates.

In 2011, he was awarded a Secretary Honor Achievement Award from the Secretary of the Department of Energy for his role on the Flow Rate Technical Group, a team spanning multiple National Laboratories that worked in response to the Deepwater Horizon oil spill. He serves on the technical advisory board of AltaRock Energy and as a member of the DOE Geothermal Strategic Planning and Analysis Working Group. In the summer of 2011, along with colleagues from Stanford, MIT, Cornell, University of Utah, Southern Methodist University, and the University of Nevada, he cofounded the National Geothermal Academy. His research interests include molecular, reservoir, and multiscale modeling applied to energy and biomedical systems.

James Bielenberg

Senior Engineering Associate
ExxonMobil's Corporate Research Laboratory

James Bielenberg is a senior engineering associate in ExxonMobil's Corporate Research Laboratory in Clinton, NJ. Jim received a BS in Chemical Engineering from the University of Nebraska (1999) followed by a MS/PhD in Chemical Engineering from the Massachusetts Institute of Technology (2000-2003). After completion of his graduate work, Jim was awarded a National Security Post-Doctoral fellowship at Los Alamos National Laboratory (2003-2005). At both MIT and LANL, Jim's research focus was on theoretical aspects of fluid flow in complex systems. Upon completion of his post-doctoral fellowship, Jim joined ExxonMobil where he has worked on new process development across a broad range of applications including heavy oil processing, electrochemistry, gasification, and biofuels. Currently, Jim is leading ExxonMobil's portfolio of activities in direct methane conversion. Jim is an author of 5 peer reviewed publications and an inventor on 15 granted US patents.

Dr. Grace M. Bochenek

Director of the National Energy Technology Laboratory

Dr. Grace M. Bochenek, Director of the National Energy Technology Laboratory (NETL), oversees a broad range of energy and environmental research and development programs that advance energy options to economically power homes, industries, and businesses while protecting the environment and enhancing U.S. energy independence.

As Director, Dr. Bochenek manages a diverse $15 billion project portfolio that seeks to discover, integrate and mature technology solutions to enhance the Nation's energy foundation and protect the environment for future generations; oversees partnerships with academia and the private sector; and manages the laboratory's technical competencies in computational science and engineering, materials engineering and manufacturing, geological and environmental systems, energy conversion engineering, and systems analysis and engineering.

As a member of the federal government Senior Executive Service with more than 30 years of executive level technical and managerial experience, Dr. Bochenek is well-versed in all aspects of full system life cycle management, including science and technology investment strategies, technology maturation and integration, procurement acquisition strategies, and performance analyses, with an emphasis on strategic alliances, partnerships, and global/international programs.

Before joining NETL in October 2014, Dr. Bochenek was the first Chief Technology Officer at the U.S. Army Materiel Command, where she served as the principal technical advisor on all engineering and scientific activities within the command and provided management oversight to the command's six regional centers, the Army Research Laboratory, and the Army Materiel Systems Analysis Agency. Prior to this position, Dr. Bochenek led research, development and engineering strategies as Director of the U.S. Army Research, Development and Engineering Command's U.S. Army Tank Automotive Research, Development and Engineering Center.

Dr. Bochenek earned a B.S. in electrical engineering from Wayne State University, an M.S. in industrial and systems engineering from the University of Michigan, and a Ph.D. in industrial systems engineering from the University of Central Florida.

Mike Casper

Senior Manager, Business and Technology Strategies
National Rural Electric Cooperative Association

Mike Casper has more than twenty five years of experience in renewable and clean energy project development, engineering, construction, operations and management. At NRECA since 2012, Casper evaluates and provides technical input on policy and legislation relevant to the electric utility sector. He also works with NRECA members to shape and conduct research designed to help the nation's more than 900 member-owned, not-for-profit electric cooperatives chart a sustainable path forward. Before coming to NRECA, Casper worked more than ten years as an independent power producer developing, constructing and operating clean energy generation facilities. Casper also spent more than ten years with a national engineering firm designing and consulting on a diverse mix of electric generation options. Casper holds an MBA from DePaul University and a BS in Mechanical Engineering from the University of Wisconsin-Platteville. Contact Mike Casper at mike.casper@nreca.coop.

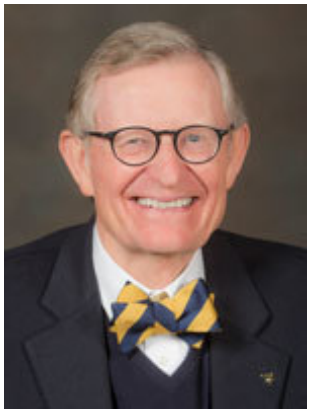
Dennis M. Davin

Secretary, Pennsylvania Department of Community and Economic Development

Dennis M. Davin was appointed to serve as Secretary of the Department of Community and Economic Development in January 2015 by Governor Tom Wolf.

Prior to his appointment, Secretary Davin served as Director of the Allegheny County Economic Development since March 2004. During his time at the Allegheny County Economic Development, Secretary Davin was responsible for the overall development and implementation of the economic development strategy for Allegheny County. He managed funding from local, state and federal resources to implement economic development activities such as: site development, new job creation initiatives, community development and affordable housing for approximately 1.25 million citizens in 130 municipalities. He also served as Director of the Allegheny County Redevelopment Authority and Executive Director of the: Industrial Development Authority, Hospital Development Authority, Higher Education Building Authority and Residential Finance Authority.

Secretary Davin is a former board member and treasurer of the Allegheny County Airport Authority; as well as a former member of the Pittsburgh Regional Alliance Partnership, Three Rivers Workforce Investment Board, International Economic Development Council, and National Association for Industrial and Office Parks, as well as a Carnegie Mellon University Center for Economic Development Fellow.



Dr. E. Gordon Gee

President, West Virginia University

Dr. E. Gordon Gee is one of America's most prominent higher education leaders, having helmed universities for more than three decades. In 2009, Time magazine named him one of the top 10 university presidents in the United States.

In 2014, Gee returned to West Virginia University, where his career as a university president began. His leadership goals include putting students first, advancing the university's research agenda, partnering with West Virginia communities and making sure that 1.8 million West Virginians know in their hearts and minds that West Virginia University is their university.

Born in Vernal, Utah, Gee graduated from the University of Utah with an honors degree in history and earned his J.D. and Ed.D. degrees from Columbia University. He clerked under Chief Justice David T. Lewis of the U.S. 10th Circuit Court of Appeals before being named a judicial fellow and staff assistant to the U.S. Supreme Court. In this role, he worked for Chief Justice Warren Burger on administrative and legal problems of the Court and federal judiciary. Gee returned to Utah as an associate professor and associate dean in the J. Reuben Clark Law School at Brigham Young University, and was granted full professorship in 1978.

One year later, he became dean of the West Virginia University College of Law, and, in 1981, was named West Virginia University president. He served in that role until 1985.

He went on to lead the University of Colorado (1985-1990), Brown University (1998-2000), and Vanderbilt University (2001-2007). He served as president of The Ohio State University from 1990 to 1997 and again from 2007 to 2013.

Gee has been a member of several education-governance organizations and committees, including the Big Ten Conference Council of Presidents, the Inter-University Council of Ohio, the Business-Higher Education Forum, and the American Association of Universities. He was chair of the American Council on Education's Commission on Higher Education Attainment and served as co-chair of the Association of Public and Land-Grant Universities' Energy Advisory Committee. In 2009, Gee was invited to join the International Advisory Board of King Adbulaziz University in Saudi Arabia.

Active in a number of national professional and service organizations during his tenures, he has served on the boards for the Rock and Roll Hall of Fame and Museum, Inc., Limited Brands, and the National 4-H Council. In 2011, Gee was appointed to serve as secretary on the Board of Directors of Ohio's economic development program, JobsOhio. In 2011-2012, he was asked by Governor Kasich to chair both the Ohio Higher Education Capital Funding Collaborative and the Ohio Higher Education Funding Commission. In December 2012, he was asked to serve on the Columbus Education Commission. And in March 2015, he was elected to the board of directors of the American Council on Education, the nation's largest higher education organization.

Gee has received a number of honorary degrees, awards, fellowships, and recognitions. He is a fellow of the prestigious American Association for the Advancement of Science, the world's largest science organization. In 1994, Gee received the Distinguished Alumnus Award from the University of Utah, as well as from Teachers College of Columbia University. In 2013, he received the ACE Council of Fellows/Fidelity Investments Mentor Award and received the Outstanding Academic Leader of the Year Award on behalf of Historically Black Colleges and Universities. He is the co-author of 11 books, including Law, Policy and Higher Education, published in 2012. He is also the author of numerous papers and articles on law and education.

Gee's daughter, Rebekah, is Secretary of Louisiana's Department of Health and Hospitals, and an assistant professor of Public Health and Medicine at Louisiana State University. She is also a Norman F. Gant/American Board of Obstetrics and Gynecology/IOM Anniversary Fellow.

Andrew Gellman

Lord Professor of Chemical Engineering
Co-Director, W.E. Scott Institute for Energy Innovation

Professor Gellman received his BS in Chemistry from the California Institute of Technology in 1981 and his Ph.D. from the University of California, Berkeley, in 1985. Thereafter, he was an ICI postdoctoral fellow at Cambridge University in Physical Chemistry. He became a faculty member of the chemistry department at the University of Illinois before joining Carnegie Mellon in 1992. He also holds courtesy appointments in Materials Science and Engineering and in Chemistry. Prof. Gellman served as Department Head of Chemical Engineering during which time he promulgated a $28 million renovation of Doherty Hall. Prof. Gellman organized a consortium involving Carnegie Mellon, University of Pittsburgh, and West Virginia University and in 2007 became the founding Director of the Institute for Advanced Energy Solutions, an outgrowth of the Department of Energy - National Energy Technology Laboratory. In 2012 he was appointed co-Director of Carnegie Mellon's W.E. Scott Institute for Energy Innovation.

Professor Gellman's group uses experimental methods to study processes occurring on surfaces such as the bonding of molecules to metal surfaces, surface structure, reaction kinetics, catalysis, friction, and lubrication. The use of surface science methods to create and study well-defined surfaces allows Professor Gellman's group to investigate surface chemistry relevant to these processes at the most fundamental level.

Professor Gellman's group has pioneered the study of enantioselective surface chemistry on naturally chiral metal surfaces. The work generates insight into some of the fundamental phenomena that lead to enantioselective adsorption and catalysis on chiral surfaces. Recent work in Professor Gellman's laboratory has focused effort on the development of instrumentation and methods for high throughput study of surface phenomena.

William Getty

President and a Trustee
Claude Worthington Benedum Foundation

Pat Getty is the President and a Trustee of the Claude Worthington Benedum Foundation, which serves West Virginia and southwestern Pennsylvania. For several years, he has been a leader of *Power of 32*, a 32-county, four-state visioning and development project in the economic region with Pittsburgh at its center, and serves on the implementation committee of the Tri-State Shale Initiative, a collaboration among the Governors of Pennsylvania, Ohio and West Virginia seeking to optimize "downstream" economic development pertaining to shale gas, especially advanced manufacturing.

Mr. Getty serves on the Boards of: the *Allegheny Conference for Community Development*; *Vibrant Pittsburgh*, which seeks to attract, retain, and elevate skilled and diverse talent; and the *Allegheny County Parks Foundation*. He was a founding Board member and past Chair of the *Fund for the Advancement of the Minorities Through Education (FAME)*, is an Emeritus Trustee and past Chair of *Shady Side Academy*, and is a past Board member and Chair of the *Boys and Girls Clubs of Western Pennsylvania*.

In West Virginia, Mr. Getty is a member of the Board of *Vision Shared,* a West Virginia state-wide economic development initiative, and the Governing Board of *Imagine West Virginia*, an independent policy research institute.

A native Pittsburgher, Mr. Getty is a graduate of Trinity College and Georgetown University Law School. He had practiced law since 1970 with the Pittsburgh firm of Meyer, Unkovic & Scott prior to becoming President of the Benedum Foundation on January 1, 1999.

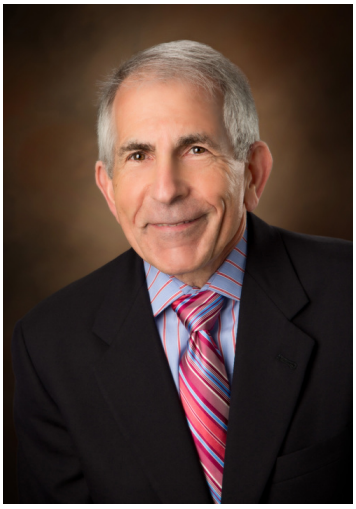
Court Gould

Executive Director, Sustainable Pittsburgh

Court Gould is executive director of Sustainable Pittsburgh, serving in this role since the organization's founding in 1998. Sustainable Pittsburgh is a public-policy advocacy group that affects decision-making in the Pittsburgh region to integrate economic prosperity, social equity, and environmental quality into sustainable solutions for communities and businesses.

With a master's in public administration from the University of Southern California, Mr. Gould's work focuses on accelerating the policy and practice of sustainable development among all sectors. Sustainable Pittsburgh's business and community networks are "go to" sources for expertise on technical issues, best practices, and testimony, and for assistance through the organization's innovative Sustainable Solutions — "extreme sustainability makeover" — consultancy. Mr. Gould routinely speaks on these issues and advises businesses and communities on strategies to implement the process of sustainable development.

His extensive community involvement includes serving as board chairman of GTECH — Growth Through Energy & Community Health — Strategies and as past chairman of the Local Government Academy board. He also is advisory board chairman for the Bayer Center for Nonprofit Management and a member of the implementation committee of the Power of 32 regional visioning project. Mr. Gould was the first chairman of the Greater Pittsburgh Nonprofit Partnership.



Michael Green

Chairman, West Virginia Growth Investment Fund

Michael Green, a retired businessman with a background in business and technology, currently serves as the Chairman of the West Virginia Growth Investment Fund, which provides mentorship and funding to entrepreneurs and early stage companies. In addition, he was appointed to the West Virginia Board of Education in 2009 to a nine-year term and currently serves as its President.

Mr. Green serves as an adviser, investor and board member for several privately held technology companies. He earned a bachelor's degree in mathematics from Boston University and a master's degree in numerical science from Johns Hopkins University.

He began his career in 1969 as a mathematician, cryptanalyst and software developer at the National Security Agency. In 1979, he began his career in the private sector when he joined Network Systems Corp., a developer and manufacturer of high-speed networking equipment, as a sales manager. After 10 years at Network Systems, he held a similar job at California-based Ultra Network Technologies. He moved to Pittsburgh-based FORE Systems Inc. in 1992, serving as senior vice president and general manager of worldwide sales. Mr. Green was recruited to join Loudcloud Inc., a technology company, and served as its president of field operations from May 2000 through May 2001.

He is a board member of the West Virginia High Technology Consortium Foundation, The West Virginia Education Alliance and serves on the Governor’s STEM Council.

Mr. Green dedicates much of his time to working with early stage companies, angel investment groups, lecturing on a variety of business and investment issues and coaching entrepreneurs.

He and his wife Diane are residents of Morgantown in Monongalia County and have four children and eight grandchildren.

Neeraj Gupta

Battelle Fellow/Senior Research Leader
Energy Business Line

Dr. Gupta, a Senior Research Leader in Battelle's Energy Business provides technical integration and program development leadership for the carbon management and subsurface resources work. Dr. Gupta has been involved in CO_2 storage technology development since mid-1990s has conducted numerous US and international projects for DOE and industry. He has been Battelle's technical or project lead for several major projects, including CO_2 storage work at the Mountaineer plant in West Virginia. As the Principal Investigator and Project Manager for Midwestern Regional Carbon Sequestration Partnership (www.mrcsp.org), Dr. Gupta oversees a consortium for regional assessment of field projects for CO_2 storage and Enhanced Oil Recovery (EOR), including an ongoing large-scale CO_2 utilization/storage test in Michigan. He has also been involved in international projects in China, Mexico, South Africa, Germany, and Japan.

Dr. Gupta's subsurface resources work includes enhanced oil recovery, brine disposal, geologic characterization; regional hydrogeology; reservoir simulations; geochemical modeling and experiments; seismic assessments; costing, and regulatory aspects. He has co-authored more than 150 reports, papers, and conference presentations.

Dr. Gupta's prior work on environmental technology includes fate and transport of contaminants, evaluation of remediation technologies, and risk assessment projects for the Air Force, Navy, EPA, DOE, and many private and international clients.

Dr. Gupta earned Bachelor's and Master's degrees in Geology from Panjab University, India, Master's degree in Geochemistry, George Washington University, and a Doctoral degree in Geological Sciences with emphasis on Hydrogeology from The Ohio State University.

M. Gary Helm

PJM Interconnection

Mr. Helm evaluates strategic issues for PJM Interconnection, focusing on the impact of environmental legislation/regulation, fuel supply and infrastructure, and broad economic trends on electricity markets and grid operations. Mr. Helm co-authored "Coal Capacity at Risk for Retirement in PJM: Impact of EPA Transport and Hazardous Air Pollutant Rules." Mr. Helm was the PJM project manager for the Eastern Interconnection Planning Collaborative's Gas-Electric System Interface Study. His current focus is on the potential impacts to PJM from the evolving resource mix.

Mr. Helm has over 25 years of industry experience, and prior to joining PJM, managed air quality issues including: policy, strategy, permitting and environmental markets for a merchant generation company

Mr. Helm earned a Bachelor of Science degree in Horticulture, a Master of Engineering degree, and a Master of Finance degree from The Pennsylvania State University.

PJM Interconnection, founded in 1927, ensures the reliability of the high-voltage electric power system serving 61 million people in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia. PJM coordinates and directs the operation of the region's transmission grid, which includes 62,556 miles of transmission lines; administers a competitive wholesale electricity market; and plans regional transmission expansion improvements to maintain grid reliability and relieve congestion. Visit PJM at www.pjm.com.

Dr. Edward D. Herderick

Additive Technologies Leader
GE Corporate Supply Chain and Operations

Dr. Edward D. Herderick is the Additive Technologies Leader for GE Corporate Supply Chain and Operations. He is responsible for leading efforts to increase the speed and depth of additive manufacturing insertion across the GE supply chain. His activities include guiding our GE Industrial businesses through strategic planning and additive technology maturation as well as teaching and educating on the latest in 3D printing. In addition, Ed is on the leadership team responsible for the launch of the new GE Center for Additive Technology Advancement in Pittsburgh, PA.

Ed joined GE after having led new product development as Director of R&D at additive technology startup rp+m in Cleveland, Ohio. Prior to that, he was Director of the Additive Manufacturing Consortium at EWI in Columbus, Ohio. Ed received his BS, MS, and PhD in materials science and engineering from The Ohio State University. After finishing his PhD, Ed served as a AAAS Congressional Fellow in Washington, DC where he was an aide in the US Senate specializing in manufacturing and defense technology issues.

He is an active member of the global materials engineering community serving on the board of directors of The Minerals, Metals, and Materials Society as well as serving as a trustee on the TMS Foundation board. He lives in Cincinnati with his wife and 2 daughters.

Joseph Hezir

Chief Financial Officer, U.S. Department of Energy

As the Department of Energy's Chief Financial Officer, Mr. Hezir works to assure the effective management and financial integrity of Department of Energy. He helps to implement and monitor Department-wide policies and systems in the areas of budget administration, program analysis and evaluation, finance and accounting, internal controls, corporate financial systems, and strategic planning.

Prior to joining the Department of Energy, Mr. Hezir worked as a Research Engineer and Executive Director of The Future of Solar Energy Study at the Massachusetts Institute of Technology's Energy Initiative. He was the Vice President and Managing Partner of EOP Group, Inc. and Executive Vice President of EOP Education, LLC and EOP Foundation, Inc. Mr. Hezir also held various roles at the Office of Management and Budget (OMB), Exxon Research and Engineering Company, the President's Reorganization Project, the U.S. Environmental Protection Agency (EPA), and was an advisor to a number of public policy and public service organizations.

Mr. Hezir co-authored two books about government budget and regulation published by the EOP Foundation: Understanding the Budget of the United States Government and Understanding the Regulatory Policy of the United States Government. He also received the President's Outstanding Federal Executive Award in 1989. Mr. Hezir attended Carnegie Mellon University, where he received a B.S. in Chemical Engineering and an M.S. from the Heinz School of Public Policy.

Fred L. King

Vice President for Research at West Virginia University

Fred L. King is the Vice President for Research at West Virginia University where he guides campus-wide efforts to support and grow the research enterprise across a diverse spectrum of specialties through a range of support activities from the administration of key grant awards to programs and processes that assist faculty in seeking and securing grant funding for research. From 1998 to 2013, he served as the Associate Dean for Research and Graduate Studies in the Eberly College of Arts and Sciences at West Virginia University

Dr. King earned a Ph.D. in analytical chemistry from the University of Virginia and a B.S. in chemistry from James Madison University. He was a National Research Council Postdoctoral Research Associate at the U.S. Naval Research Laboratory from 1988 to 1990. In 1990, he joined the faculty of the Eberly College of Arts and Sciences as an assistant professor in the Department of Chemistry in 1990. He was promoted to associate professor in 1996 and professor in 2002. His research specialty at WVU has been fundamental characterization and analytical development of optical spectroscopy and mass spectrometry techniques.

He has been the principal investigator or associate principal investigator on multiple sponsored research projects from numerous federal agencies and the private sector including: Office of Naval Research, Martin Marietta Energy Systems, the WV Coal Energy Research Bureau, the U.S. Department of Energy, the National Science Foundation and the National Institutes of Health. He has served as a guest scientist at Oak Ridge National Laboratory and as an adjunct professor in the WVU School of Pharmacy. He received the Finnigan MAT Distinguished Young Investigator in Academia Award in 1993.

In addition to performing his administrative duties at the University, Prof. King continues to maintain an active research group.

Joe Manchin

United States Senator

U.S. Senator Joe Manchin (D-W.Va.) was sworn into the United States Senate on November 15, 2010 to fill the seat left vacant by the late Senator Robert C. Byrd. For Senator Manchin, serving as West Virginia's Senator is truly an honor and a privilege.

Born and raised in the small coal mining town of Farmington, W.Va., Sen. Manchin grew up learning the values that all West Virginians share – family, common sense, fairness and hard work. As a small businessman, he learned firsthand from his grandfather, Papa Joe, who was an Italian immigrant and the town grocer, the importance of serving the public. As a young man, his beloved grandmother, Mama Kay, inspired Senator Manchin's belief in public service through her unflagging compassion and desire to help those less fortunate. More than anything, it is his family and the values he learned growing up among the hardworking men and women of West Virginia that define who Senator Manchin is and the public servant he strives to be.

From his days as a state legislator to his six years as Governor to his current role, Senator Manchin has always been committed to his philosophy of "retail government"-- in other words, connecting with all of his constituents and making service to them his top priority.

Throughout his public life, he has never let politics or ideology stand in the way of commonsense solutions. Instead, he believes that only by putting politics aside and working hard to bring people together can we do what is right for West Virginia and the nation.

He began his tenure as West Virginia's 34th governor in January 2005. Then-Governor Manchin approved millions of dollars in tax relief for West Virginia's citizens and businesses, fixed the state's workers' compensation system, established the first comprehensive teacher pay package in more than 15 years and dramatically decreased the state's debt. In six years, more than $13 billion in business investments were made, and West Virginia was often cited nationally for its strong fiscal management. During his term as Governor, he worked closely with Republicans and Democrats to cut taxes, reduce regulations, attract record investments, create new jobs and expand vital social services for seniors and the poor, all while leaving the state with budget surpluses every year.

As a Senator, Joe Manchin is committed to bringing this same spirit of bipartisanship to Washington. As he has done throughout his entire life, he remains committed to working with Republicans and Democrats to find commonsense solutions to the problems our country faces and is working hard to usher in a new bipartisan spirit in the Senate and Congress.

Legislatively, job creation is Senator Manchin's top priority, and he believes that government should act as a partner, not an adversary, in helping to create the environment that produces good American jobs. Senator Manchin also firmly believes that our nation can and must do what he did in West Virginia - put our fiscal house in order. He believes we must find commonsense ways to cut spending while keeping our promises to our seniors and veterans by protecting Social Security and Medicare.

Senator Manchin is strongly committed to developing a balanced national energy plan that utilizes all of our resources and recognizes that fossil fuels will be a vital part of our energy mix for decades to come. He believes that a balanced, commonsense approach that considers the needs of our environment and the demands of our economy, can and must be developed if we are to achieve energy independence within this generation.

Senator Manchin currently serves on the Senate Energy and Natural Resources Committee, the Senate Armed Services Committee, the Senate Committee on Commerce, Science and Transportation, and the Senate Committee on Veterans' Affairs - four critical committees that tackle the important work of addressing our nation's energy needs, standing up for the members of the military, defending our small banks and local credit unions, helping the housing market recover and keeping our promises to seniors.

KEY HIGHLIGHTS:

Senator Manchin has served in several leadership capacities on various associations, including: Chairman of the National Governors Association, Chairman of the Southern States Energy Board, President of the Council of State Governments, Chairman of the Democratic Governors Association and Chairman of the Southern Governors' Association.

Sen. Manchin served as Secretary of State from 2000 to 2004, and his office was known for excellent customer service. He was a state legislator from 1982 to 1996, where he earned a reputation for standing up for West Virginians.

Sen. Manchin became a successful businessman after attending West Virginia University on a football scholarship.

Sen. Manchin is an avid pilot, outdoorsman, hunter, angler and motorcyclist. He has been married for more than four decades to the former Gayle Conelly of Beckley. They have three children: Heather, Joseph IV and Brooke, and are the proud grandparents of Joseph V, Sophie, Kelsey, Madeline, Chloe, Jack, Carly, Vivian, Beaux and Knox.

Jan Mares

Senior Policy Advisor , Resources for the Future

Jan Mares was previously a business liaison and deputy director at the Private Sector Office of the Department of Homeland Security (DHS). During the Reagan administration, Mares was an assistant secretary of commerce for import administration and a senior policy analyst at the White House, where he was involved with environment, energy, trade, and technology issues. He also served as assistant secretary of energy for international affairs and energy emergencies; assistant secretary of energy for policy, safety and environment; and assistant secretary of energy for fossil energy. For six months, he was the acting under secretary of energy. Before entering federal service, Mares was with Union Carbide Corporation for 18 years, half in the Law Department, working on antitrust compliance and purchasing issues, and half in its chemical business, including leading an effort for three years to create a chemicals joint venture with a Middle East government company and being the operations/ profit manager for several groups of industrial chemicals. Subsequent to his service in the Reagan administration, he worked with the Washington, DC, law firm Shaw Pittman, the Synthetic Organic Chemical Manufacturers Association, and the EOP Group (a Washington, DC, environment, energy, and budget consulting firm.

Jeffrey McDaniel

Executive-in-Residence, Innovation Works

WestVirginiaUniversity.

Jeffrey McDaniel is an Executive-in-Residence at Innovation Works (IW) in Pittsburgh, Pennsylvania. Innovation Works is one of the country's most active investors in seed-stage technology companies. Jeff leads IW's early-stage and follow-on investments in Energy and Advanced Manufacturing, serving on the boards of several clean energy and advanced materials companies. He also mentors companies in IW's accelerator programs, AlphaLab and AlphaLab Gear.

Prior to Innovation Works, Jeffrey was in charge of business development, sustainability and strategy for the emerging technology R&D portfolio for Westinghouse Electric Company. Mr. McDaniel also held various roles at the Ex One Company, a global manufacturing technology company. There, he led the successful commercialization of Imagen, LLC, a 3D printing manufacturer of dental implant and bio-medical devices. Before those roles he was an associate in the corporate division of global law firm Reed Smith, LLP.

Mr. McDaniel also served in the United States Navy as a Surface Warfare Officer.

Jeffrey McDaniel holds a Bachelor of Science degree from the United States Naval Academy and a JD from the University of Pittsburgh School of Law.

Representative David B. McKinley, P.E.

U.S. House of Representatives
West Virginia 1st Congressional District

David Bennett McKinley was born in Wheeling in 1947. He attended public schools and worked his way through college graduating from Purdue University with a degree in Civil Engineering. After college he spent the next 12 years in the construction industry and taught night classes in local technical colleges.

David then established McKinley and Associates – an architectural and engineering company that has grown to include offices in Wheeling and Charleston, WV and Washington, PA. During his career as a Professional Engineer, David has been on the Board of Directors of the state engineering society and on the Board of the National Society of Professional Engineers representing the interests of West Virginia.

As a successful former small businessman, David has created hundreds of jobs and understands the vital role of small businesses in creating private sector jobs and strengthening the economy. He has been recognized twice by West Virginia Executive Magazine as one of the 50 most influential people in West Virginia.

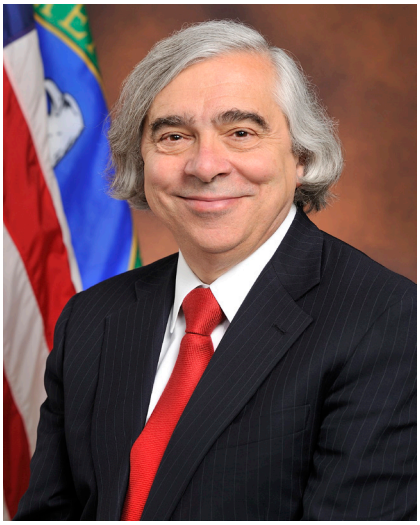
From 1981 through 1994, he represented the Third Delegate District in the West Virginia Legislature and in 1990 was elected as Chairman of the West Virginia Republican Party Executive Committee.

David was sworn into office on January 3, 2011. He serves on the House of Representatives' Energy and Commerce Committee, where he is vice-chairman of the Oversight and Investigations Subcommittee.

He knows the coal industry is the backbone of West Virginia's economy and has worked tirelessly to stop the Obama Administration's War on Coal. Three times the House has passed his legislation to protect the 316,000 Americans reliant on the coal ash recycling industry. He has worked to protect coal miners' pensions and healthcare benefits they worked hard to earn. He has fought the onslaught of burdensome regulations coming out of the White House that have crippled the coal industry and threaten our long-term energy security.

As an individual with significant hearing impairment and a grandfather to a child with special needs, David McKinley is no stranger to overcoming the obstacles of disabilities. He has used his role on the Committee overseeing health policy, Medicare, and Medicaid to push for better coverage for families and the elderly.

David is married to the former Mary Gerkin from New Martinsville, West Virginia and is a proud father of four children and six grandchildren. David is a seventh generation resident of Wheeling and West Virginia. His passion for the families of West Virginia inspires his votes in Congress and he always remembers who he works for.



Dr. Ernest Moniz

United States Secretary of Energy

As United States Secretary of Energy, Dr. Ernest Moniz is tasked with implementing critical Department of Energy missions in support of President Obama's goals of growing the economy, enhancing security and protecting the environment. This encompasses advancing the President's all-of-the-above energy strategy, maintaining the nuclear deterrent and reducing the nuclear danger, promoting American leadership in science and clean energy technology innovation, cleaning up the legacy of the cold war, and strengthening management and performance.

Prior to his appointment, Dr. Moniz was the Cecil and Ida Green Professor of Physics and Engineering Systems at the Massachusetts Institute of Technology (MIT), where he was a faculty member since 1973. At MIT, he headed the Department of Physics and the Bates Linear Accelerator Center. Most recently, Dr. Moniz served as the founding Director of the MIT Energy Initiative and as Director of the MIT Laboratory for Energy and the Environment where he was a leader of multidisciplinary technology and policy studies on the future of nuclear power, coal, nuclear fuel cycles, natural gas and solar energy in a low-carbon world.

From 1997 until January 2001, Dr. Moniz served as Under Secretary of the Department of Energy. He was responsible for overseeing the Department's science and energy programs, leading a comprehensive review of nuclear weapons stockpile stewardship, and serving as the Secretary's special negotiator for the disposition of Russian nuclear materials. From 1995 to 1997, he served as Associate Director for Science in the Office of Science and Technology Policy in the Executive Office of the President.

In addition to his work at MIT, the White House and the Department of Energy, Dr. Moniz has served on a number of boards of directors and commissions involving science, energy and security. These include President Obama's Council of Advisors on Science and Technology, the Department of Defense Threat Reduction Advisory Committee, and the Blue Ribbon Commission on America's Nuclear Future.

A member of the Council on Foreign Relations, Dr. Moniz is a Fellow of the American Association for the Advancement of Science, the American Academy of Arts and Sciences, the Humboldt Foundation, and the American Physical Society.

Dr. Moniz received a Bachelor of Science degree summa cum laude in Physics from Boston College, a Doctorate in Theoretical Physics from Stanford University, and honorary degrees from the University of Athens, Boston University, the University of Erlangen-Nurenberg, Iowa State University, University of Massachusetts Dartmouth, Michigan State University and Universidad Pontificia de Comillas.

Mark A. Nydam

Principal, HarbourVest Partners, LLC

Mr. Mark A. Nydam is a Principal at HarbourVest Partners, LLC. Mr. Nydam joined HarbourVest Partners in 2012 and focuses on clean technology and renewable energy investments, and managing relationships with clients and prospects. He has more than 15 years of experience in private equity and more than 20 years of experience in the global energy sector including clean technologies and renewable energy.

Previously, Mr. Nydam served as a Managing Director at PCG Asset Management, LLC. He joined PCG in March 2007 and specialized in clean energy and technology. At PCG, Mr. Nydam created and led the Clean Energy and Technology Group as well as international business development efforts. He was also responsible for investments in middle-market cleantech companies and cleantech funds with successes in areas ranging from solar cells to fuel cells.

Mr. Nydam has worked on clean energy and clean technologies from the perspective of venture capital and private equity firms, major Middle Eastern energy producers, international oil and gas companies, corporate investors, and national governments, and has a broad perspective to the clean energy and technology sector.

Prior to joining PCG Asset Management, LLC, Mr. Nydam was a Program Director and Principal at Booz Allen Hamilton Holding Corporation where he directed private equity-related clean technology and renewable energy engagements in the Middle East. He founded Signal Hill Advisors. Prior to Signal Hill, Mr. Nydam was a Principal at L.E.K. Consulting providing top-tier private equity firms with investment strategy, investment identification, and investment due diligence advisory services. He spent three years working as a Foreign Affairs Officer at the U.S. Department of State where he developed and managed a multi-million dollar development assistance program that helped Middle Eastern and Asian governments attract western private investment into their oil and gas sectors. Mr. Nydam also spent five years managing a natural resources investment advisory firm. He serves as a Director of MPH Energy Midco LP, ReCommunity Recycling LLC, Re Community Holdings II, Inc. and served as a Director at SpectraWatt, Inc.

Mr. Nydam received an M.B.A., with Honors, a Masters in International Relations both from the University of Chicago in 1990 and an M.S. and a B.S. in Geology and Geophysics from Yale University

Sean I. Plasynski, Ph.D.

Deputy Director & Chief Operating Officer (Acting),
Laboratory Operations Center

Sean Plasynski provides strategic direction, oversight, and management of NETL's support functions and services. As Chief Operating Officer, Dr. Plasynski manages a comprehensive, fully integrated program of laboratory support operations and services including safe and secure facilities, cybersecurity, and IT infrastructure.

Dr. Plasynski has held numerous management and technical positions over his 26-year career at NETL, including Director of the Strategic Center of Coal, Director of the Office of Coal and Power R&D, and Sequestration Technology Manager. He has been involved in a wide spectrum of energy technology development, including advanced power and environmental systems, solids transport, biomass co-firing, and carbon capture and storage. Dr. Plasynski has also served on a team addressing critical U.S. infrastructure vulnerabilities for homeland security.

He holds a B.S., M.S., and Ph.D. in chemical engineering from the University of Pittsburgh and an M.B.A from the University of Pittsburgh's Katz Graduate School of Business.

Stewart Prager, Ph.D.

Director, Princeton Plasma Physics Laboratory

Stewart Prager, Ph.D., is the director of the Princeton Plasma Physics Laboratory. Under Prager's leadership, the Laboratory completed the $94 million upgrade of its main experiment, the National Spherical Torus Experiment.

Other projects launched at PPPL under Prager's leadership include a new facility to investigate magnetic reconnection, a process that is responsible for the northern lights, solar flares and geomagnetic storms that can disrupt cell phone service and black out power grids. The Laboratory has also established a plasma nanotechnology laboratory and with Princeton University has founded the Center for Heliospheric Physics, which studies the volatile region of space that encompasses the solar system.

Prager has worked closely with other leaders of the research community to develop strategies for the U.S. fusion program.

Prager joined PPPL from the University of Wisconsin-Madison, where he led the Madison Symmetric Torus fusion experiment and a center that studied laboratory and astrophysical plasmas. While at Wisconsin, Prager co-discovered the "bootstrap current" – a finding that has changed the way tokamaks are designed.

Scott Rotruck

Director of Energy and Transportation Services Spilman Thomas & Battle, PLLC.

Scott Rotruck is the Director of Energy and Transportation Services for Spilman Thomas & Battle, PLLC. He joined Spilman in 2013, after working 10 years in railroad operations, 20 years in regulatory and external affairs in the coal, oil & natural gas industries and six combined years as the Economic Development Director and member of the adjunct faculty at the WVU College of Business & Economics teaching Entrepreneurship. He is an accredited (Angel) investor and participant in several early stage companies in WVa.

Scott is a 1977 graduate of WVU, has an MBA from Frostburg State University and is a certified Kauffman Foundation Entrepreneurship Instructor. Scott was appointed by four West Virginia Governors, to chair several statewide boards in economic development, tourism and venture funding. Born in Huntington, WVa., he grew up in Keyser, and now lives in Morgantown, with his wife Carol. They have three children and two grandchildren.

Chris Stadelman

Chief of Staff

West Virginia Governor's Office

Chris Stadelman was named Chief of Staff for Governor Earl Ray Tomblin June 22, 2016. Mr. Stadelman previously served as Gov. Tomblin's Director of Communications. Prior to joining the Tomblin Administration, Mr. Stadelman spent 20 years working at newspapers in West Virginia, including 10 years at the Charleston Daily Mail where he served as business editor, city editor and managing editor.

Mr. Stadelman and his wife, Kelly, owned and operated The Parsons Advocate, a weekly newspaper in Tucker County, for seven years before he began working in public relations, where he worked for a number of health care, tourism, and energy-related clients. He also served as a spokesman for Governor Tomblin's 2011 and 2012 campaigns and most recently served as director of outreach for the West Virginia Press Association.

A graduate of John Marshall High School, Stadelman attended Marshall University where he was a member of the Society of Yeager Scholars and earned a bachelor's degree in journalism and a minor in political science.

Chris and Kelly live in South Charleston with their two Labradors, Bettis and Crosby.

Denise Swink

Ms. Swink retired from Federal Service (2004) after 35 years' experience spanning a variety of programs at the U.S. Geological Survey, the U.S. Environmental Protection Agency and the U.S. Department of Energy, and is currently serving as an independent consultant to private sector, government and non-profit organizations.

At the Department of Energy, Ms. Swink held positions as Director, Office of Planning and Environment, Office of Fossil Energy; Deputy Assistant Secretary, Office of Industrial Technologies, Office of Energy Efficiency and Renewable Energy; and Deputy Director and Acting Director, Office of Energy Assurance.

The last two decades Ms. Swink held management/supervisory positions, and the last decade she was a member of the Senior Executive Service.

Ms. Swink has worked at the highest levels of government and the private sector, both nationally and internationally, on topics including: fossil energy technology advancement for extraction, transport and utilization of resources; manufacturing productivity and efficiency with emphasis on technology advancement and adoption; electricity infrastructure development; and safety and reliability of the entire energy infrastructure.

To enhance the efficiency and competitiveness of industry, Ms. Swink created and led extensive public/private partnerships with private, state and academic entities to: develop strategies promoting innovation; create, fund and implement plans; and monitor results and effectiveness. Private sector participants ranged from CEO's to plant operation personnel.

As the energy infrastructure is the bedrock infrastructure for the resilience of all other critical infrastructures, Ms. Swink has substantial knowledge of interdependencies among infrastructures.

Dave van der Wiel

Director, Babcock & Wilcox Research Center

Dave van der Wiel is the Director of the Babcock & Wilcox Research Center and oversees a portfolio of Technology Development projects focusing on energy & environmental technologies. In this role, he is responsible for laboratory and pilot testing, strategic research program alignment and collaborations with B&W subsidiaries and external partners. B&W's main areas of current research include waste-to-energy, industrial & utility environmental products, BFBs for biomass-to-energy, CFB boiler emissions and chemical looping processes. His background includes 20 years of domestic and international work experience in catalysis, energy, materials science, environmental technologies, microtechnology and gas-to-liquids processes.

Dr. van der Wiel previously worked in various R&D roles at Saint-Gobain NorPro, Velocys, Battelle Memorial Institute and Pacific Northwest National Laboratory. In these positions he has worked on joint R&D projects with the world's top chemical companies, catalyst manufacturers, energy companies and several governmental organizations, including the DOE, DARPA and NASA.

He holds a Ph.D. Chemical Engineering from Iowa State University and is a co-inventor on over 20 granted patents.

Steven Winberg

Program Manager, Battelle Memorial Institute

Steven Winberg has over 35 years of experience in the energy industry, ranging from power generation equipment design and installation, to use of innovative fuels and holds two patents related to NOx emissions reduction using coal and natural gas. Mr. Winberg has worked on a variety of emerging energy initiatives including carbon capture and sequestration, coal-to-liquids, greenhouse gas reduction technology, fluidized bed combustion, emulsified fuels, fuel cells, alternative fuel vehicles, and coal-water slurry applications.

Prior to joining Battelle, Mr. Winberg served as Vice President for CONSOL Energy Research & Development. He began his career with Foster Wheeler as a start-up engineer on coal-fired utility boilers, and spent 14 years with Consolidated Natural Gas working on various power development projects and environmental and regulatory issues. He represented the gas industry on EPA's Acid Rain Advisory Committee and participated in various regulatory rulemaking initiatives involving end-use application of natural gas.

Mr. Winberg has a B.S. degree in nuclear science from the State University of New York Maritime College and a MBA from the University of Pittsburgh.

Battelle is the world's largest nonprofit research and development organization, with over 22,000 employees globally. A 501(c)(3) charitable trust, Battelle manages the world's leading national laboratories and maintains a contract research portfolio spanning consumer and industrial, energy and environment, health and pharmaceutical and national security. Battelle's own mission includes a strong charitable commitment to community development and education with staff volunteer efforts including; STEM education programs; and philanthropic projects.

Michael N. Worley

U.S. Department of Energy (DOE) Office of Nuclear Energy (NE)

Mr. Worley is the Director for Integrated Safety and Program Assurance, with responsibilities to plan and execute the Nuclear Energy University Programs and Integrated University Program. Prior to this assignment, Mr. Worley was the Director for Laboratory Facilities Management, with line management responsibility for the nuclear facilities and safeguards & security programs at the Idaho National Laboratory, including operations at the Advanced Test Reactor.

Prior to joining NE, Mr. Worley served in the Office of Environmental Management (EM) as the Idaho High Level Waste Program Manager and as the Mound Site Program Manager. Other DOE assignments included serving on the staff of the Office of the Departmental Representative to the Defense Nuclear Facilities Safety Board and as a member of the Office of Defense Programs team responsible for the restart of the K Reactor at the Savannah River Site. Before joining DOE, Mr. Worley served in the U.S. Naval Nuclear Propulsion Program as a submarine officer.

Mr. Worley is a graduate of the U.S. Naval Academy where he earned a B.S. in Political Science and Government and The Johns Hopkins University where he received his M.S. in Environmental Engineering and Science.

David Zaziski

Federal Business Development Advisor/Consultant
Siluria Technologies, Inc.

Dr. David Zaziski has over 12 years' experience working at the intersection of new technology, public policy, and commercializing products from concept in areas including Energy, Cleantech, MEMS, aerospace, advanced materials, nanotechnology, and defense.

Dr. Zaziski is currently Director of Government Affairs and Business Development at Siluria Technologies, Inc. Siluria is pioneering the commercial production of fuels and chemicals made from clean, abundant natural gas.

Prior to Siluria, Dr. Zaziski led the business development team at Crossbow Technology, Inc, a leading developer of MEMS based inertial systems for navigation, guidance and control systems. Crossbow was acquired by Moog, Inc. in 2011. Before Crossbow, Dr. Zaziski built up $18M in government programs at Nanosys, Inc., a nanotechnology products company. Dr. Zaziski is also a consultant/advisor to numerous venture backed and F500 technology companies on matters of government strategy, proposal development and strategy execution.

Dr. Zaziski earned his Ph.D. in Materials Chemistry at the University of California, Berkeley and B.S. in Chemistry at University of Michigan. Dr. Zaziski is the author of over 7 patents (issued and pending) and publications in leading journals including Science and NanoLetters.