



The WVU Energy Institute: Building on our Strengths, Expanding our Impact



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Verl O. Purdy Chair of Engineering
Chemical Engineering

Academy of Chemical and Biomedical
Engineers
Annual Meeting
April 26, 2018



Energy Institute Vision and Mission

Mission

To promote, coordinate and expand the vital impacts and value of West Virginia's energy assets and capabilities for the people of West Virginia, the mid-Appalachian region, the nation and world

Vision

By serving as a catalytic hub, continually discovering and developing transformational pathways connecting WVU energy researchers, programs, facilities, capabilities and students/workforce entrants with the future of energy

(A) Expand the Portfolio

Strategically drive, enable and guide expansion of WVU's energy research portfolio to \$60m annually by 2025 in coordination with the needs of policy makers and industry

(B) Promote Development

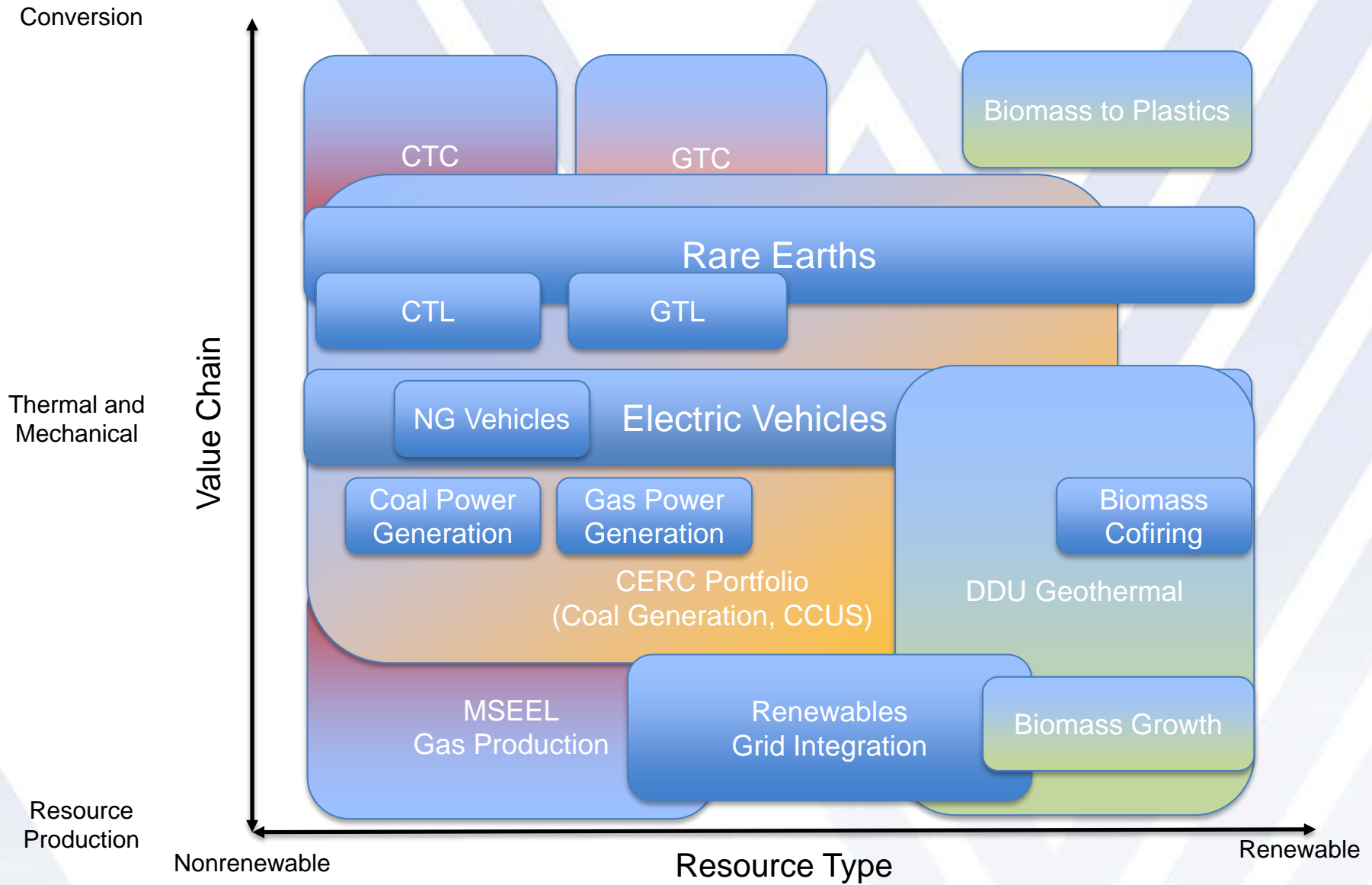
Promote economic development within West Virginia and the region by aligning West Virginia's energy assets with the emerging needs, directions, and challenges of the energy sector

(C) Elevate the Workforce

Elevate West Virginia's workforce by aligning, coordinating, and expanding opportunities through interdisciplinary energy academic programs and initiatives

2025
Goals





Major Initiatives and Partnerships



- Natural gas utilization
 - Shale gas Mountain of Excellence faculty hires
 - Shale Gas Center launched
 - Appalachian Storage Hub
 - National Academy of Science Roundtable on Unconventional Hydrocarbons



NATIONAL ACADEMY OF SCIENCES

- Coal utilization
 - U.S.-China Clean Energy Research Centers
 - Advanced Coal Technology Consortium
 - Rare earth and critical materials



- Sustainable energy pathways
 - The Nature Conservancy
 - NNMI Institutes



- Smart Manufacturing Hub NNMI
 - AICHE RAPID Manufacturing



International MOUs

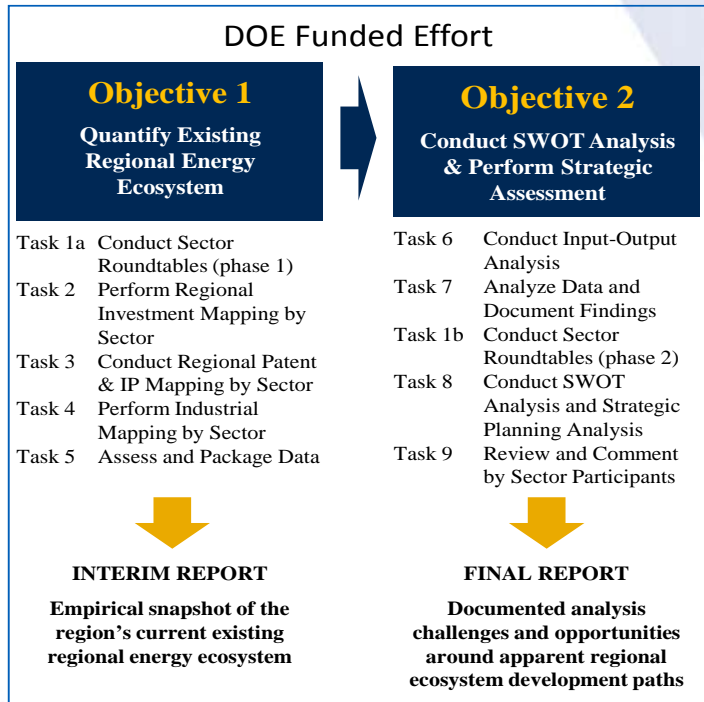
- China
- Paraguay
- Iceland
- Canada
- Middle East
 - Bahrain
 - Qatar
 - Kuwait



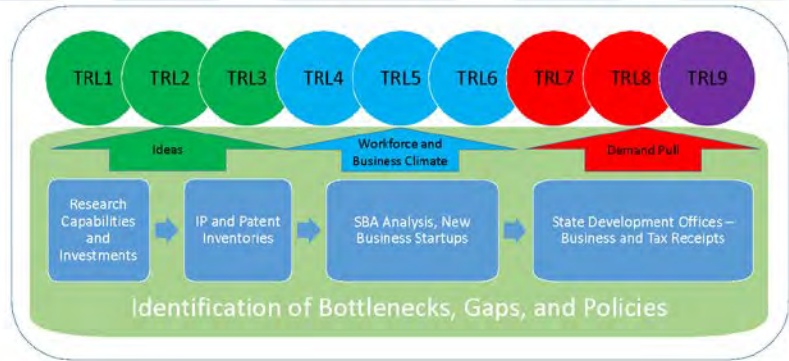
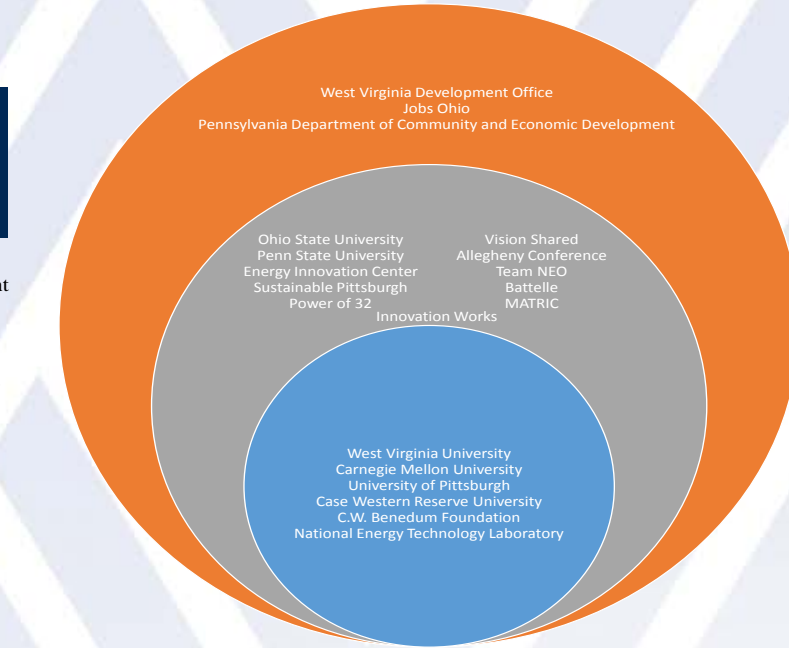
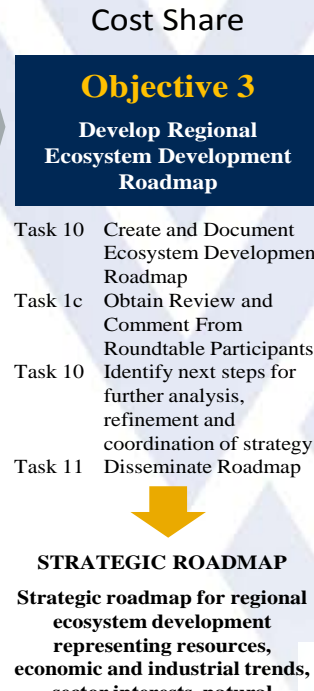
Tri-State University Energy Alliance
CMU, Pitt, CWRU, WVU




Techbelt Region Energy Ecosystem Characterization (TREEC): Analyzing Energy Innovation's Opportunities and Challenges in Western Pennsylvania, Northeast Ohio, and Northern West Virginia



Roadmap to be provided to DOE for review and comment prior to dissemination



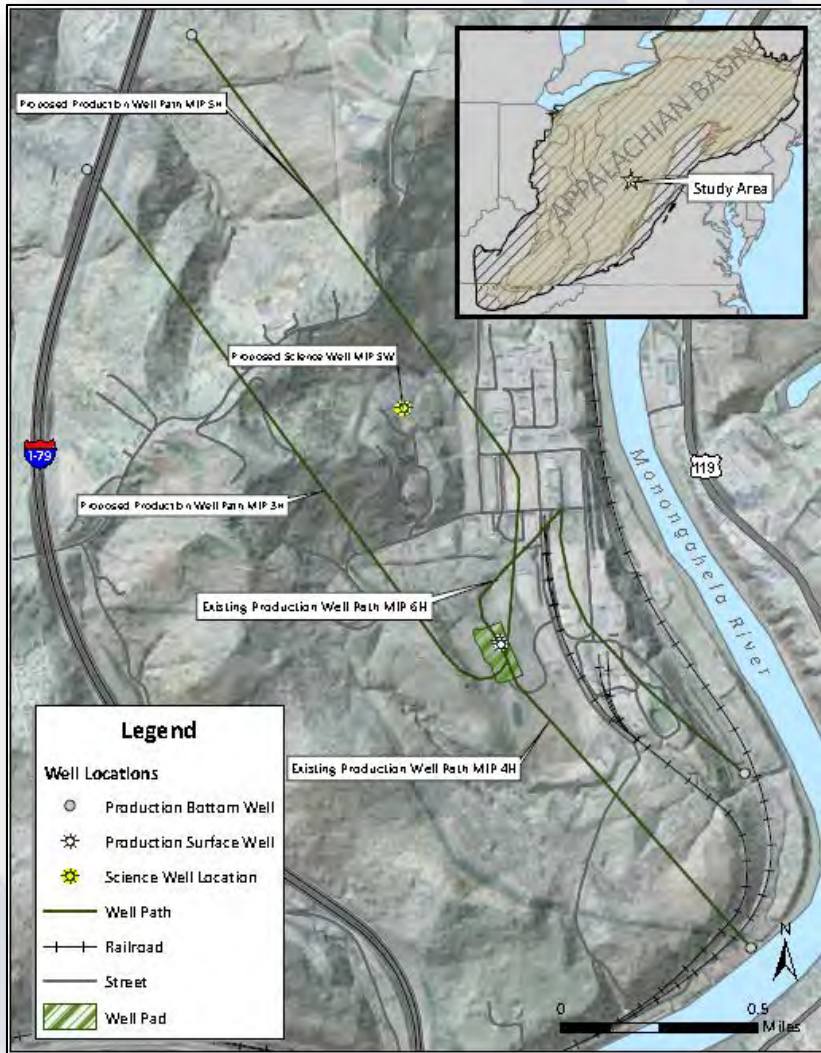
MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY

MSEEL

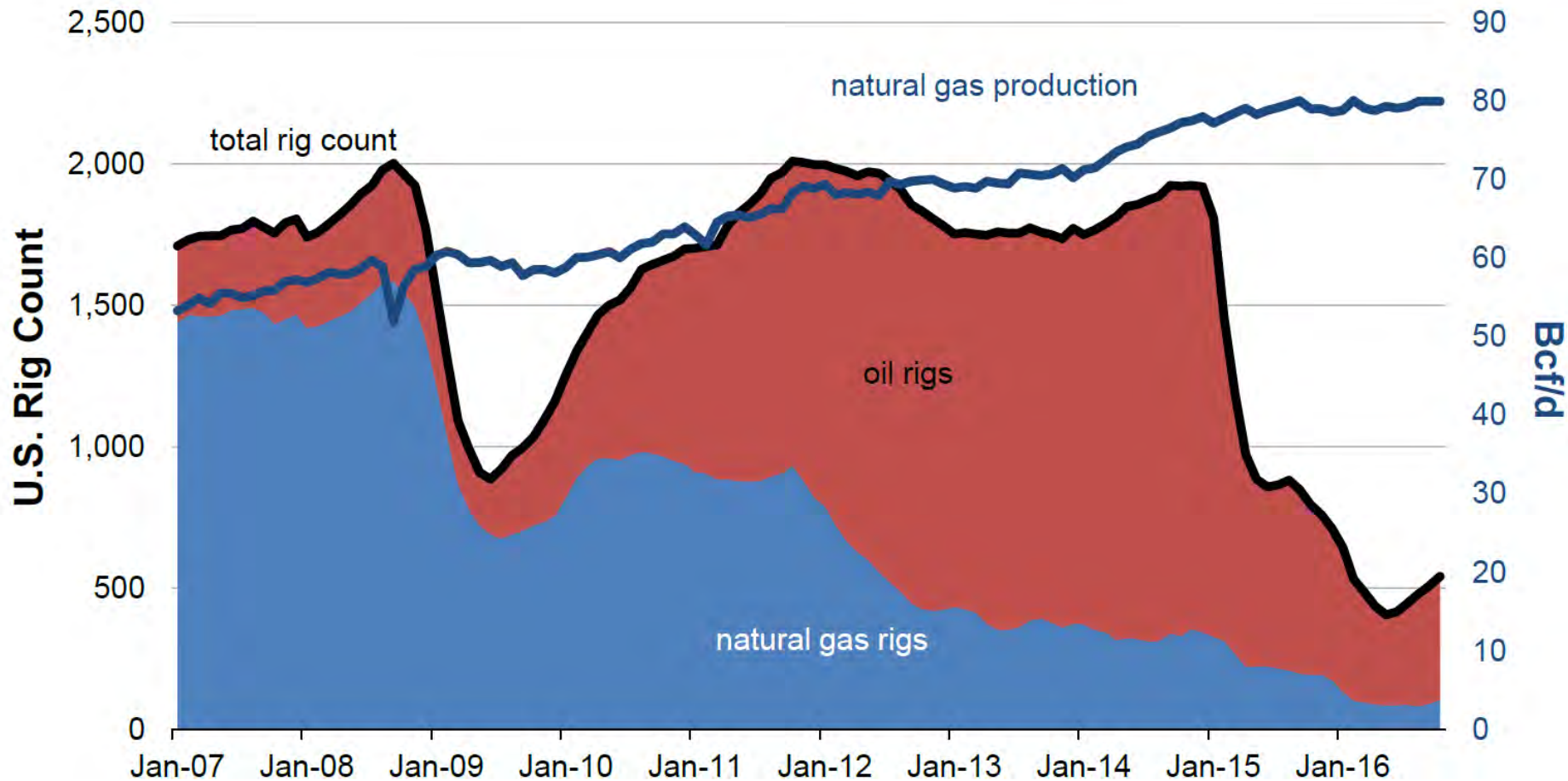
The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a **long-term collaborative field site** to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development



MSEEL Site



U.S. Rig Count and Production



Source: Baker Hughes, Inc. rig count, EIA Monthly Total Marketed Production



Which Term Applies?

- Natural Gas
 - Natural gas is a fossil fuel used as a source of energy for heating, cooking, and electricity generation.
- Liquefied Natural Gas (LNG)
 - Liquefied natural gas is natural gas (predominantly methane, CH_4 , with some mixture of ethane C_2H_6) that has been converted to liquid form for ease and safety of non-pressurized storage or transport.
- Natural Gas Liquids (NGL)
 - Natural gas liquids are hydrocarbons—in the same family of molecules as natural gas and crude oil, composed exclusively of carbon and hydrogen. Ethane, propane, butane, isobutane, and pentane are all NGLs



Natural Gas Liquids

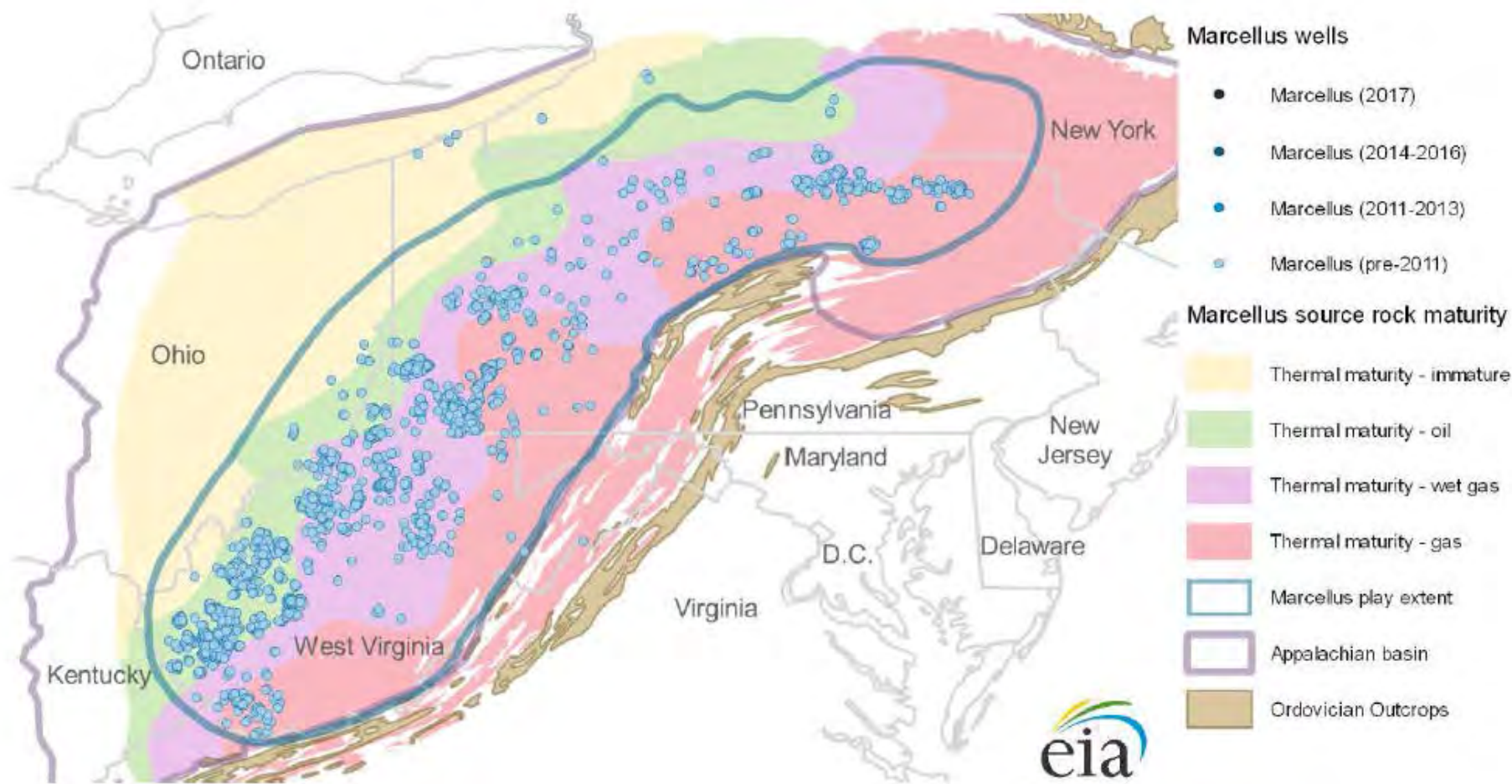
Table 1. Natural gas liquids, uses, products, and consumers

| NGL | Chemical formula | Uses | End-use products | End-use sectors |
|---|---|---|--|--|
| Ethane | C ₂ H ₆ | Petrochemical feedstock for ethylene production; power generation | Plastics; anti-freeze; detergents | Industrial |
| Propane | C ₃ H ₈ | Fuel for space heating, water heating, cooking, drying, and transportation; petrochemical feedstock | Fuel for heating, cooking, and drying; plastics | Industrial (includes manufacturing and agriculture), residential, commercial, and transportation |
| Butanes: normal butane and isobutane | C ₄ H ₁₀ | Petrochemical and petroleum refinery feedstock; motor gasoline blending | Motor gasoline; plastics; synthetic rubber; lighter fuel | Industrial and transportation |
| Natural gasoline (pentanes plus) | Mix of C ₅ H ₁₂ and heavier | Petrochemical feedstock; additive to motor gasoline; diluent for heavy crude oil | Motor gasoline; ethanol denaturant; solvents | Industrial and transportation |

Source: US DOE Natural Gas Primer: With a Focus on the Appalachian Region, Dec. 2017



Figure 10. Marcellus Wells¹⁷



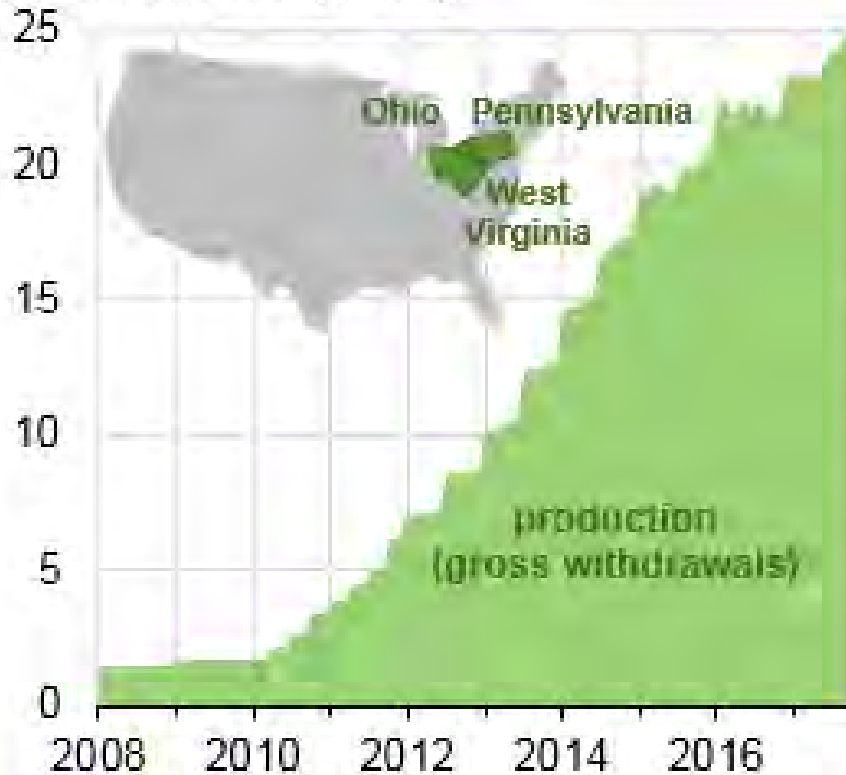
Source: US DOE Natural Gas Primer: With a Focus on the Appalachian Region, Dec. 2017



Natural gas production in Pennsylvania, Ohio, West Virginia growing faster than demand

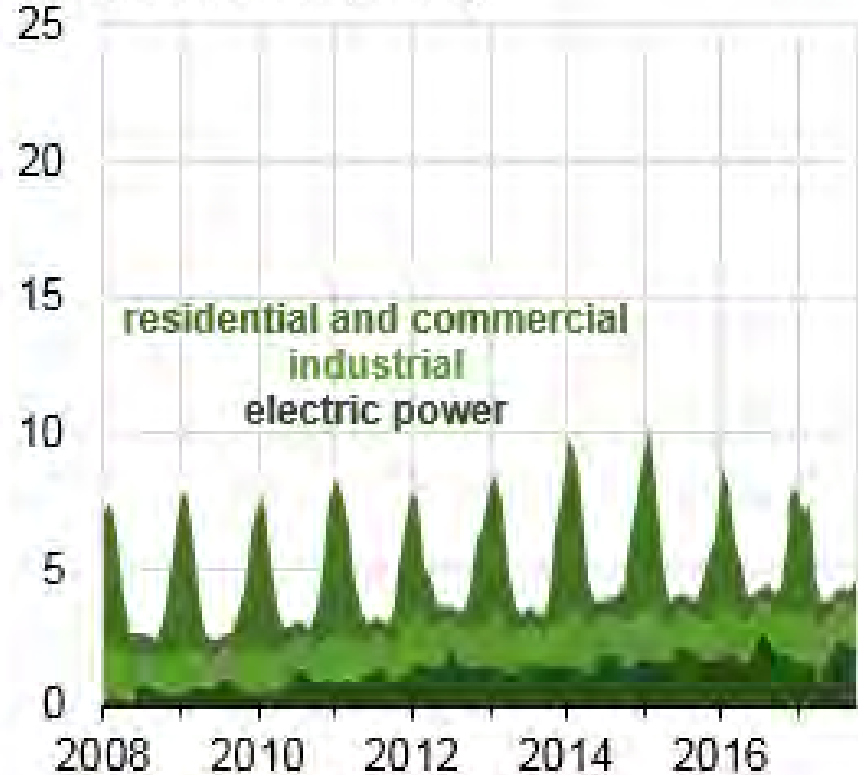
Natural gas in Ohio, Pennsylvania, and West Virginia (Jan 2008-Oct 2017)

production
billion cubic feet per day



consumption
billion cubic feet per day

consumption
billion cubic feet per day



Source: EIA, "Natural Gas Production in Pennsylvania, Ohio, West Virginia growing faster than demand." Jan. 2018



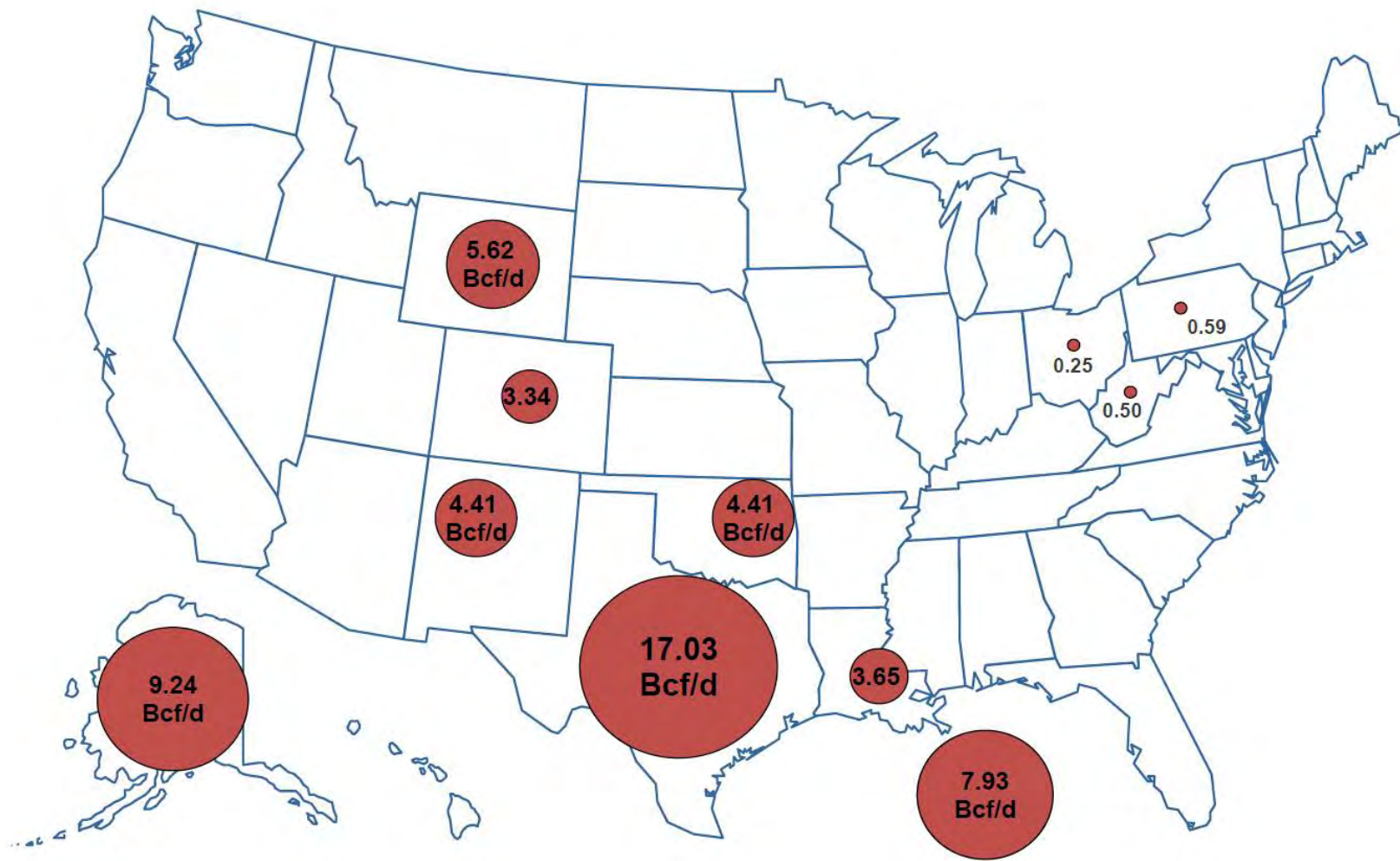
Where does it all go?

- Question: Where is all that natural gas going?
- Answer: Appalachian production has been displacing Gulf Coast supply, freeing additional U.S. production for export by pipeline and as liquefied natural gas (LNG).



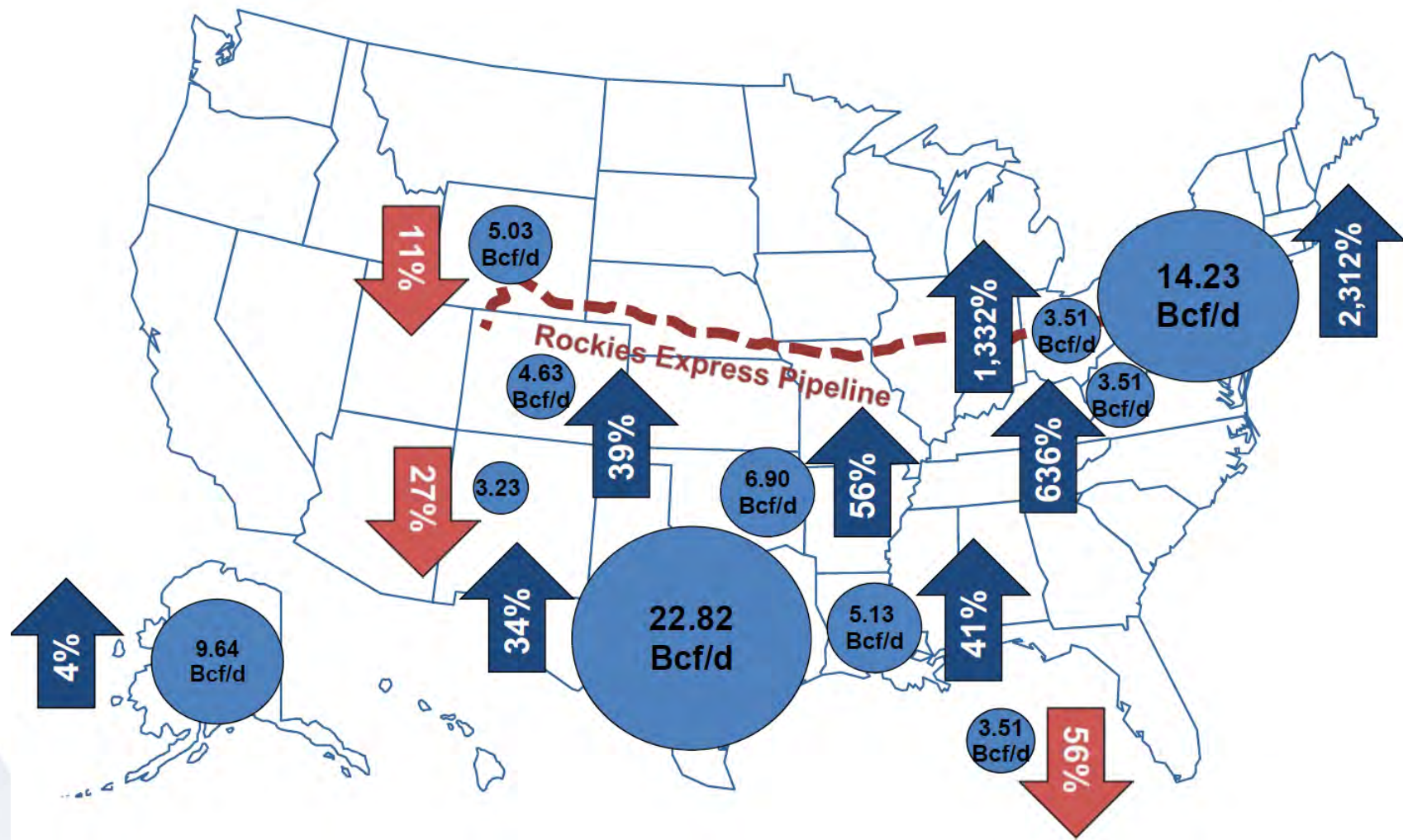
Natural Gas Production Shifts

U.S. Natural Gas Production in Jan. 2006, Bcf/d



Natural Gas Production Shifts

U.S. Natural Gas Production, Jan. 2006 compared to Jan. 2016, Bcf/d

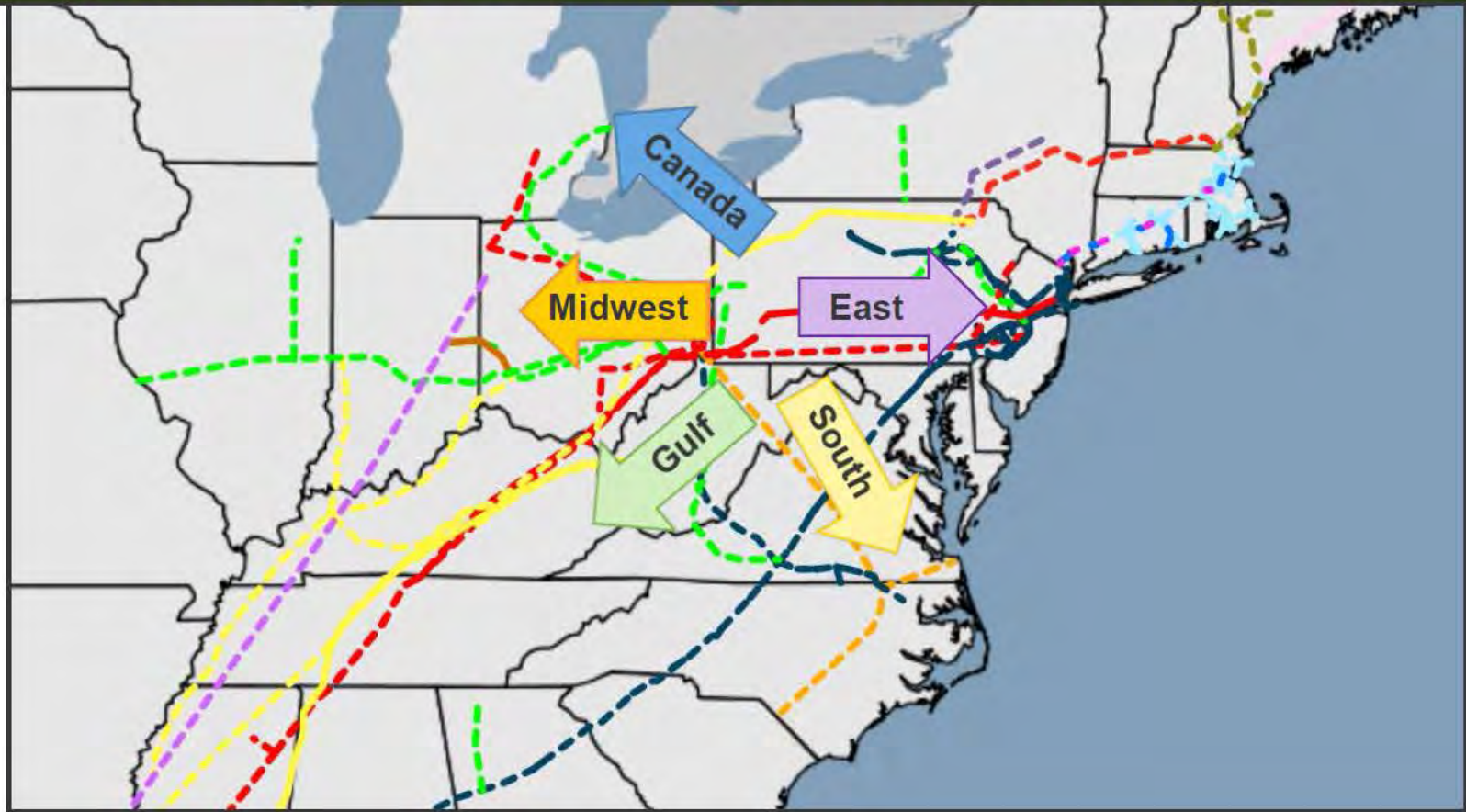


Source: EIA, January Monthly Natural Gas and Petroleum Report



Natural Gas Infrastructure Development

~20 Bcf/d of new natural gas pipeline takeaway capacity from 30+ pipeline builds, expansions and reversals to move gas out of the Appalachian basin by 2019.



Source: RBN Energy and EIA





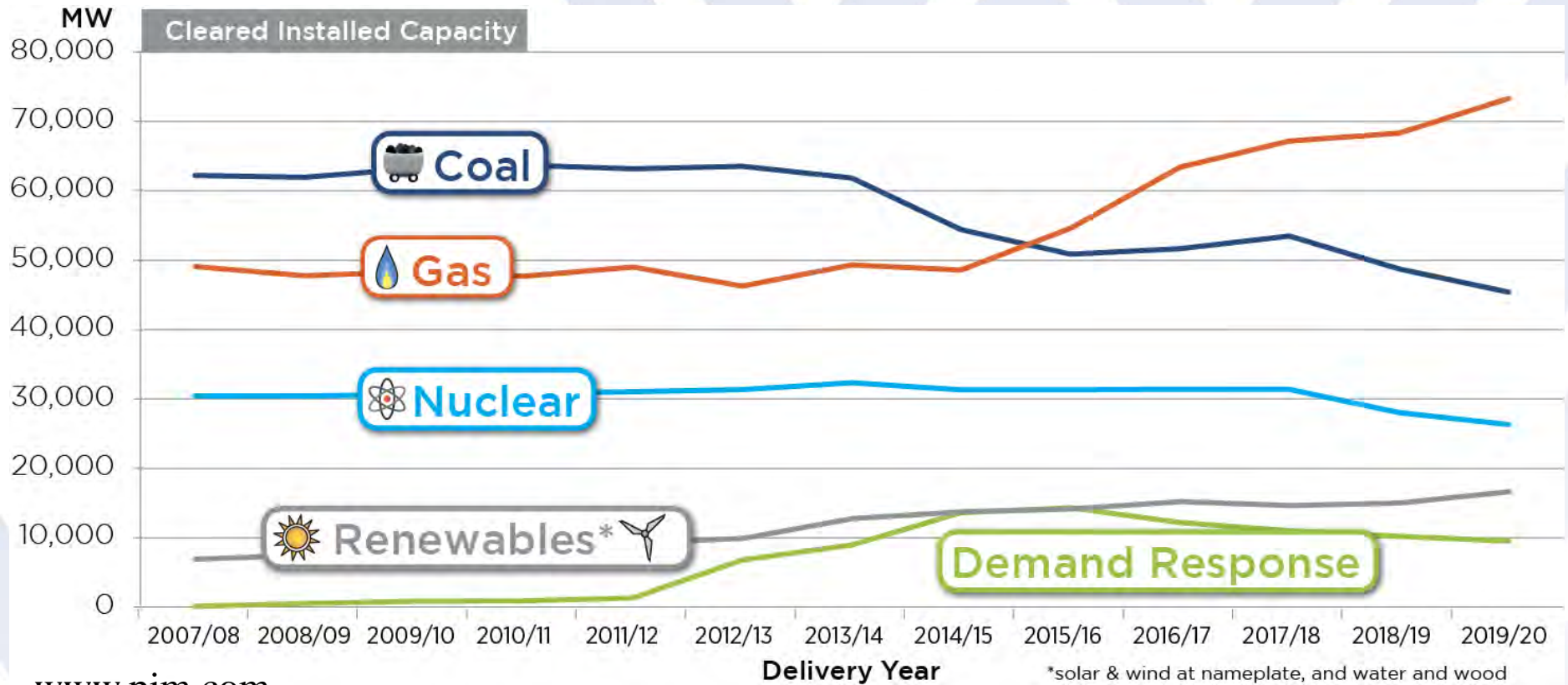
Eastern Interconnection

PJM

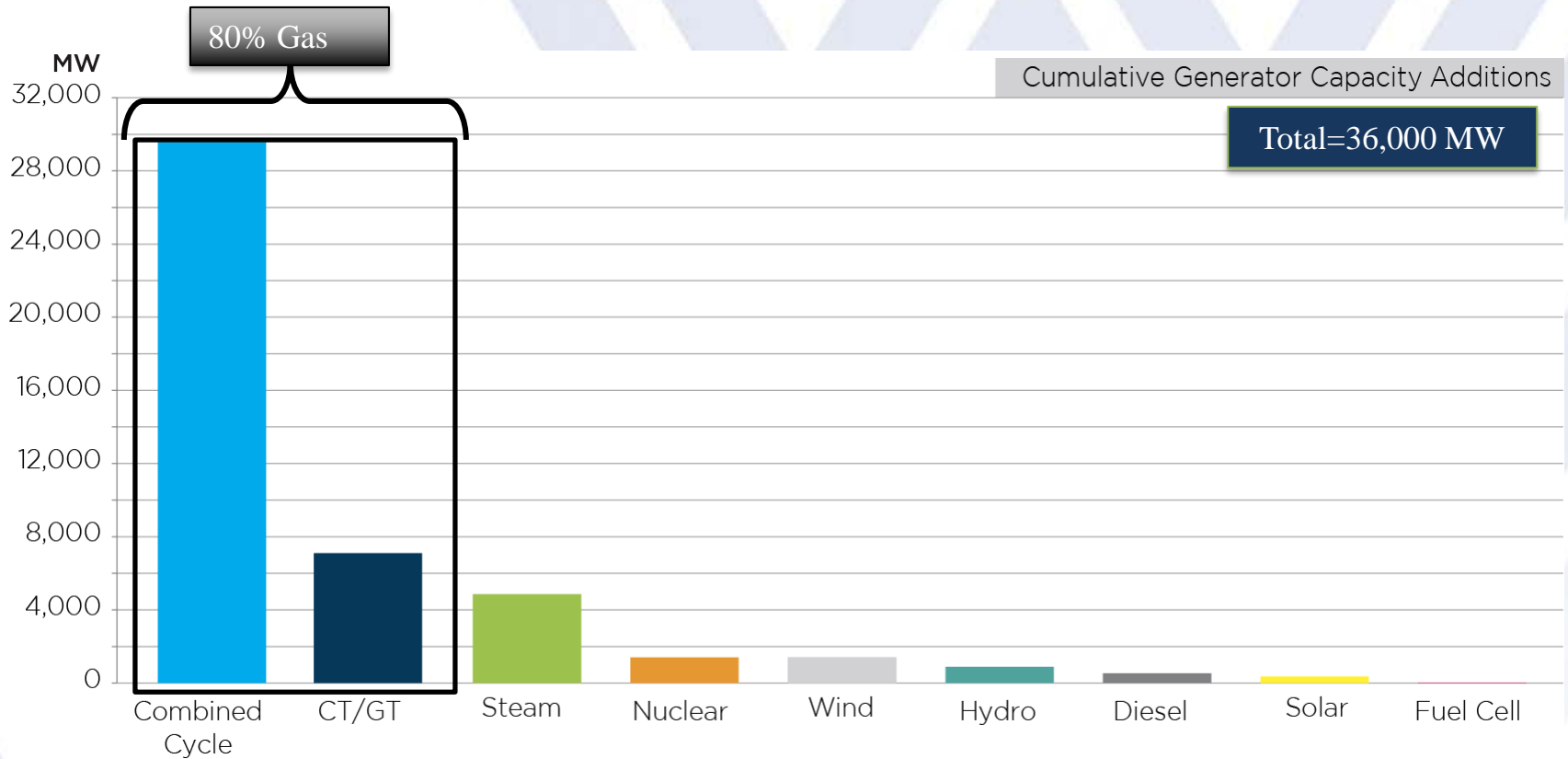
21% of U.S. GDP produced in PJM



Capacity Market Managing Change



Capacity Market Additions Since 2007/08



www.pjm.com



Tri-State Shale Coalition

- WV, PA, and OH
 - Governors signed collaboration agreement
 - Infrastructure
 - Research
 - Workforce Development
 - Publicity and Marketing
 - <http://www.tristateshalesummit.com/>



Tri-State Shale Coalition

Ohio, Pennsylvania, and West Virginia working together, building on their shale assets.

Connect with us:



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Team NEO
PBoulter@TeamNEO.org



Ken Zapinski
Allegheny Conference
kzapinski@alleghenyconference.org



Cory Dennison
Vision Shared
president@visionshared.org

If your company is looking to expand in petrochemicals, plastics, or converted products, you should be considering the tri-state region of Ohio, Pennsylvania, and West Virginia.

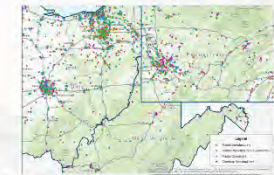
We have customers, suppliers, a globally competitive technical workforce, and a leading educational/innovation ecosystem to help your company stay on the leading edge of market- and technology-advances.

The **Tri-State Shale Coalition** represents the three states working together to build a global petrochemical hub. This "super region" is on the verge of game-changing petrochemical, plastics fabrication and advanced manufacturing jobs and investments. Public and private partners representing workforce development, academia, and economic development in the tri-state region recognize this opportunity and are visibly and strategically aligned to promote the super region as the new **"Global Petrochemical Hub."**

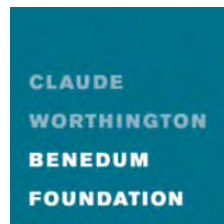
We have the **largest concentration of end-use customers** in the United States, giving you unprecedented access to help you effectively service and supply the strongest economy in the globe. We have a

globally-competitive supply chain that serves both US and international markets.

Petrochemical & Downstream Manufacturers within 400 Miles: **17,477** Companies



Chemical Manufacturers (purple): **3,271** Companies
Rubber Mfg. & Conv. (brown): **1,811** Companies
Plastic Converters (blue): **8,182** Companies
Plastics Mfg. (green): **1,187** Companies



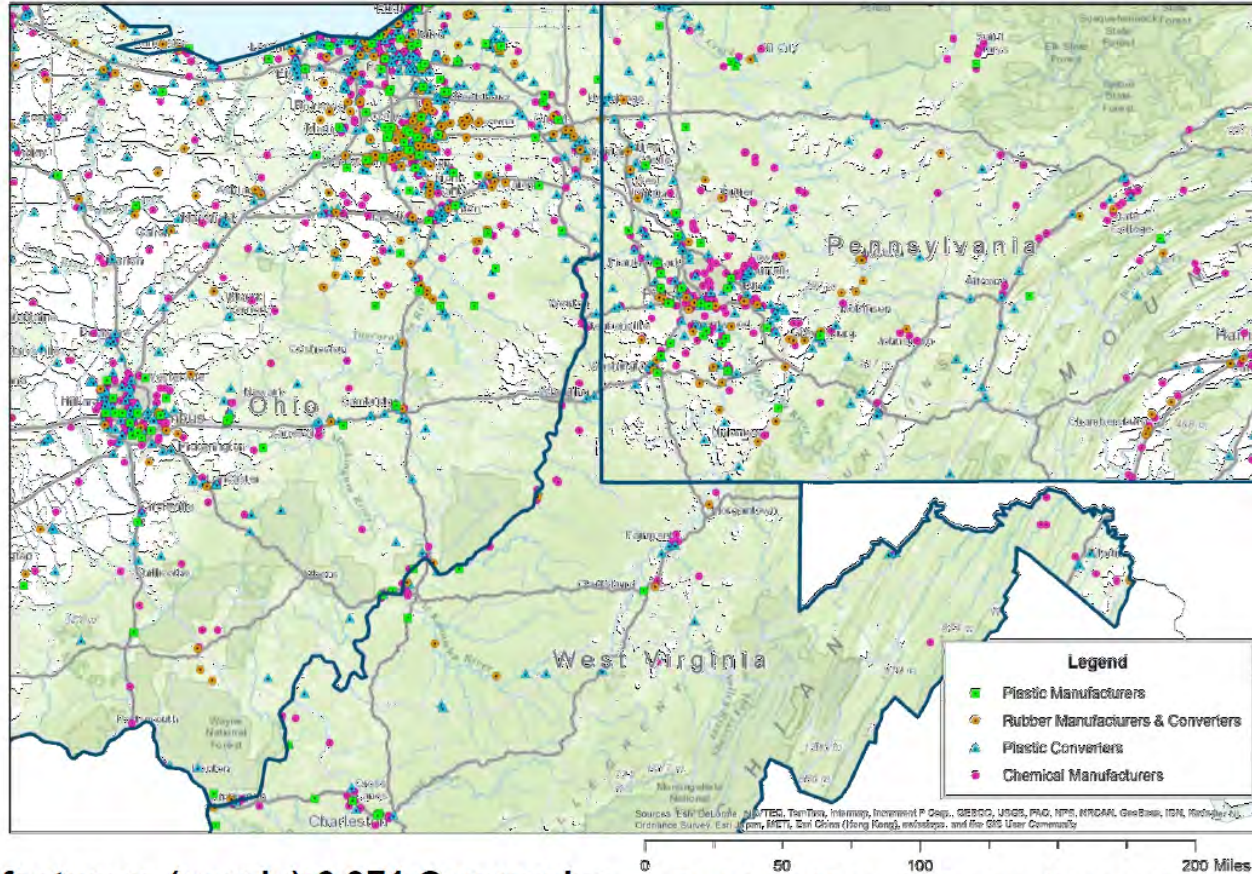
TRI-STATE SHALE SUMMIT



October 13, 2015



Petrochemical & Downstream Manufacturers within 400 Miles: 17,477 Companies



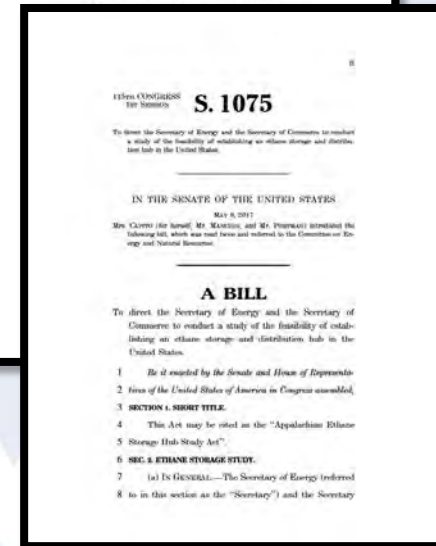
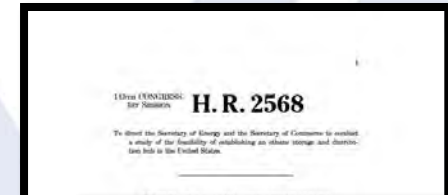
Chemical Manufacturers (purple): 6,371 Companies
Plastic Converters (blue): 8,147 Companies

Rubber Mfg. & Conv. (brown): 1,812 Companies
Plastics Mfg. (green): 1,147 Companies



Regional Cooperation – Congressional Action

- **H.R.2568 - Appalachian Ethane Storage Hub Study Act**
 - McKinley (R-WV), Jenkins (R-WV), Mooney (R-WV), Murphy (R-PA), Johnson (R-OH)
- **S.1075 - Appalachian Ethane Storage Hub Study Act**
 - Capito (R-WV), Manchin (D-WV), Portman (R-OH)
- **S.1337 - A bill to amend the Energy Policy Act of 2005 to make certain strategic energy infrastructure projects eligible for certain loan guarantees, and for other purposes**
 - Manchin (D-WV), Capito (R-WV), Brown (D-OH)
- **S.1340 - A bill to provide for an expedited permitting process for critical energy infrastructure projects relating to the establishment of a regional energy hub in Appalachia, and for other purposes**
 - Capito (R-WV)



Regional Cooperation – Congressional Action

H.R.2568 and S.1075 - Appalachian Ethane Storage Hub Study Act

To direct the Secretary of Energy and the Secretary of Commerce to conduct a study of the feasibility of establishing an ethane storage and distribution hub in the United States.

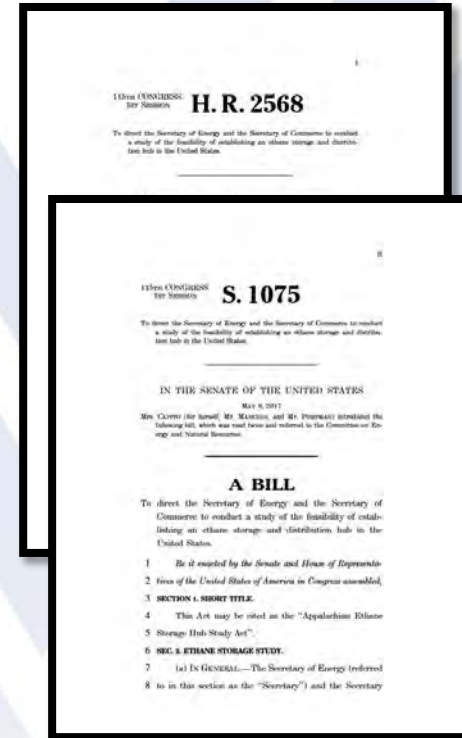
In general.—The Secretary of Energy (referred to in this section as the “Secretary”) and the Secretary of Commerce, in consultation with other relevant Federal departments and agencies and stakeholders, shall conduct a study of the feasibility of establishing an ethane storage and distribution hub in the Marcellus, Utica, and Rogersville shale plays in the United States.

The study conducted shall include—

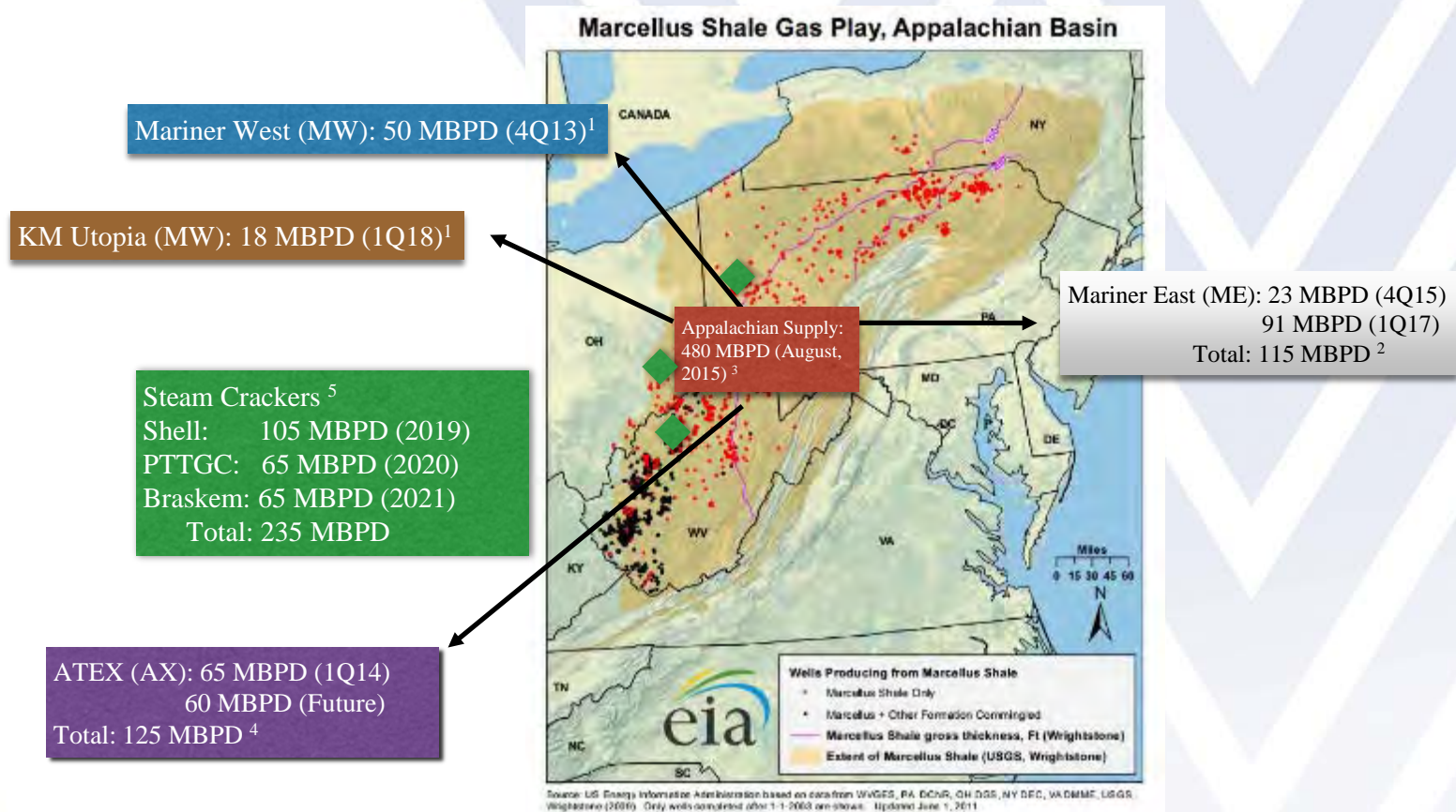
- (1) an examination of, with respect to the proposed ethane storage and distribution hub—
 - (A) potential locations;
 - (B) economic feasibility;
 - (C) economic benefits;
 - (D) geological storage capacity capabilities;
 - (E) above-ground storage capabilities;
 - (F) infrastructure needs; and
 - (G) other markets and trading hubs, particularly hubs relating to ethane; and
- (2) the identification of potential additional benefits of the proposed hub to energy security.

Publication of results.—Not later than 2 years after the date of enactment of this Act, the Secretary and the Secretary of Commerce shall—

- (1) submit to the Committee on Energy and Commerce of the House of Representatives and the Committees on Energy and Natural Resources and Commerce, Science, and Transportation of the Senate a report describing the results of the study under subsection (a); and
- (2) publish those results on the Internet websites of the Departments of Energy and Commerce, respectively.



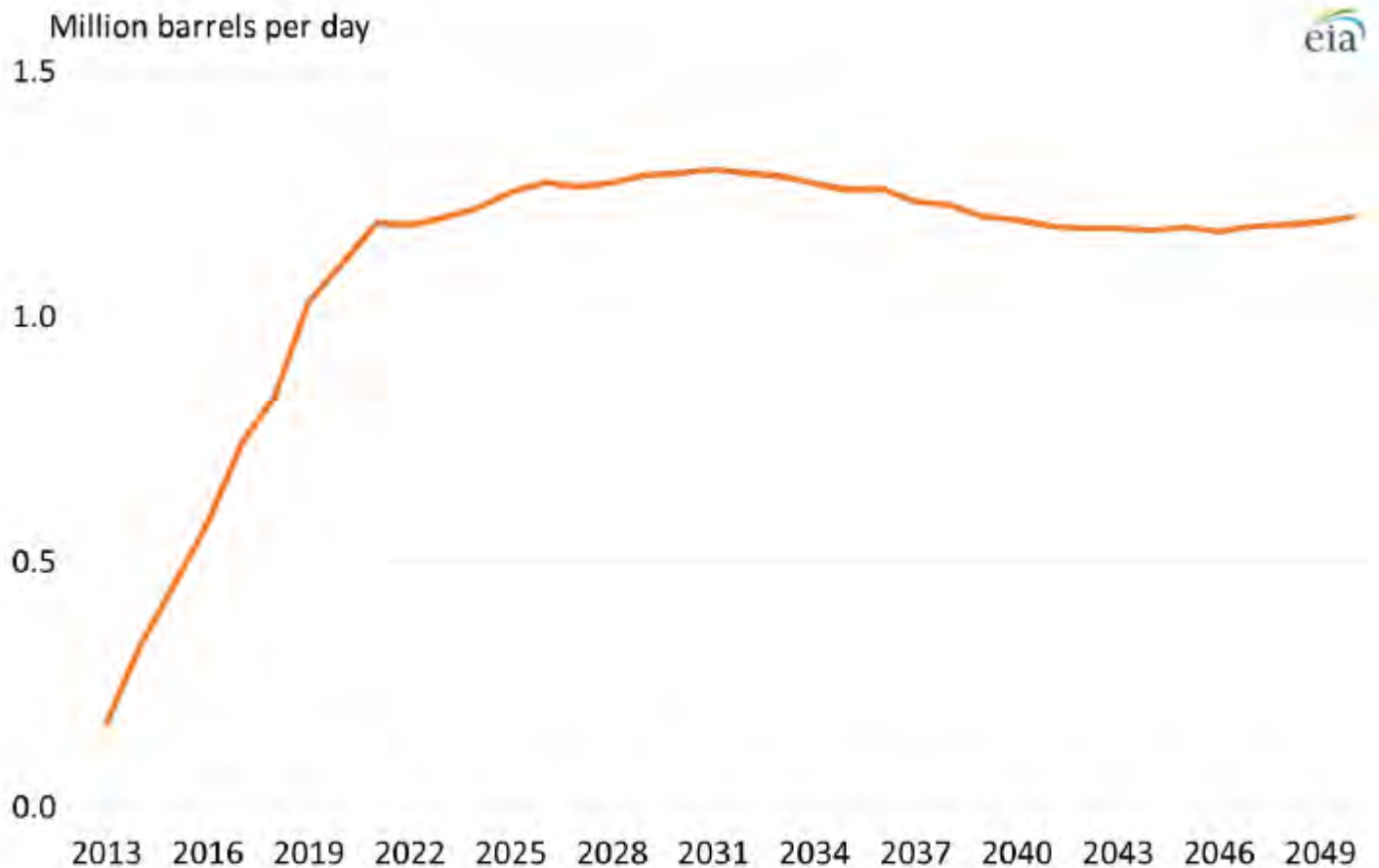
Estimated Ethane Supply and Announced Demand



August 2015 it is estimated that 350 MBPD was rejected — the announced demands/off takes will provide a relevant “frac” spread for the Appalachian Basin with the majority of ethane leaving the region (Europe, Texas, Canada)



Figure 7. Appalachia NGL Production¹⁴

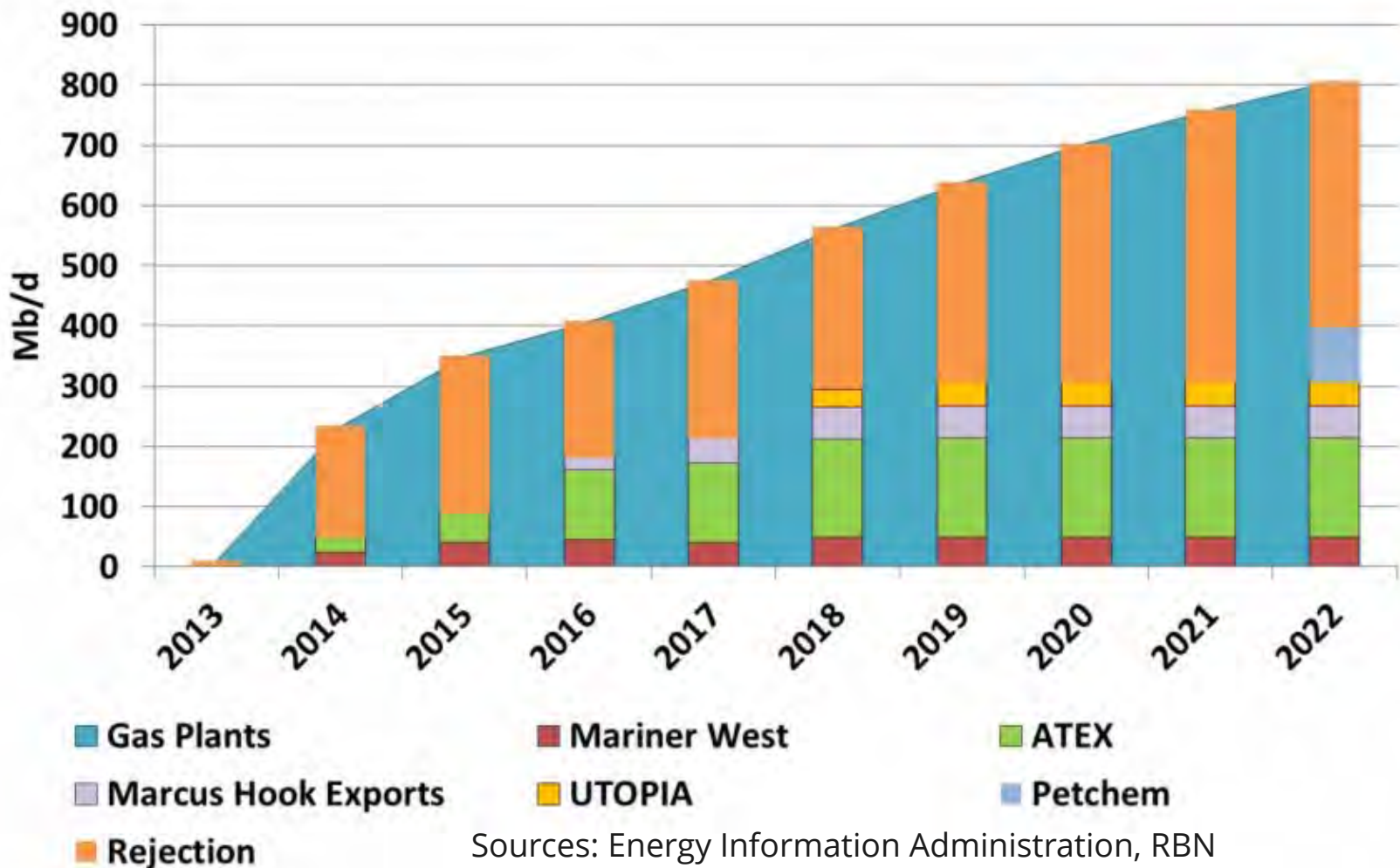


NGL output will continue to grow through 2025 as producers target wet gas areas, and then experience a plateau and eventual gradual decline to 2050. NGL output from 2017 to 2025 will more than double from 403,000 b/d in 2017 to 1.3 million b/d in 2030. NGL output is projected to reach 1.2 million b/d in 2050.

Source: US DOE Natural Gas Primer: With a Focus on the Appalachian Region, Dec. 2017



Marcellus and Utica Ethane Growth Scenario Supply/Demand, 2013-2022



Sources: Energy Information Administration, RBN
October 19, 2017 RBN Energy, LLC

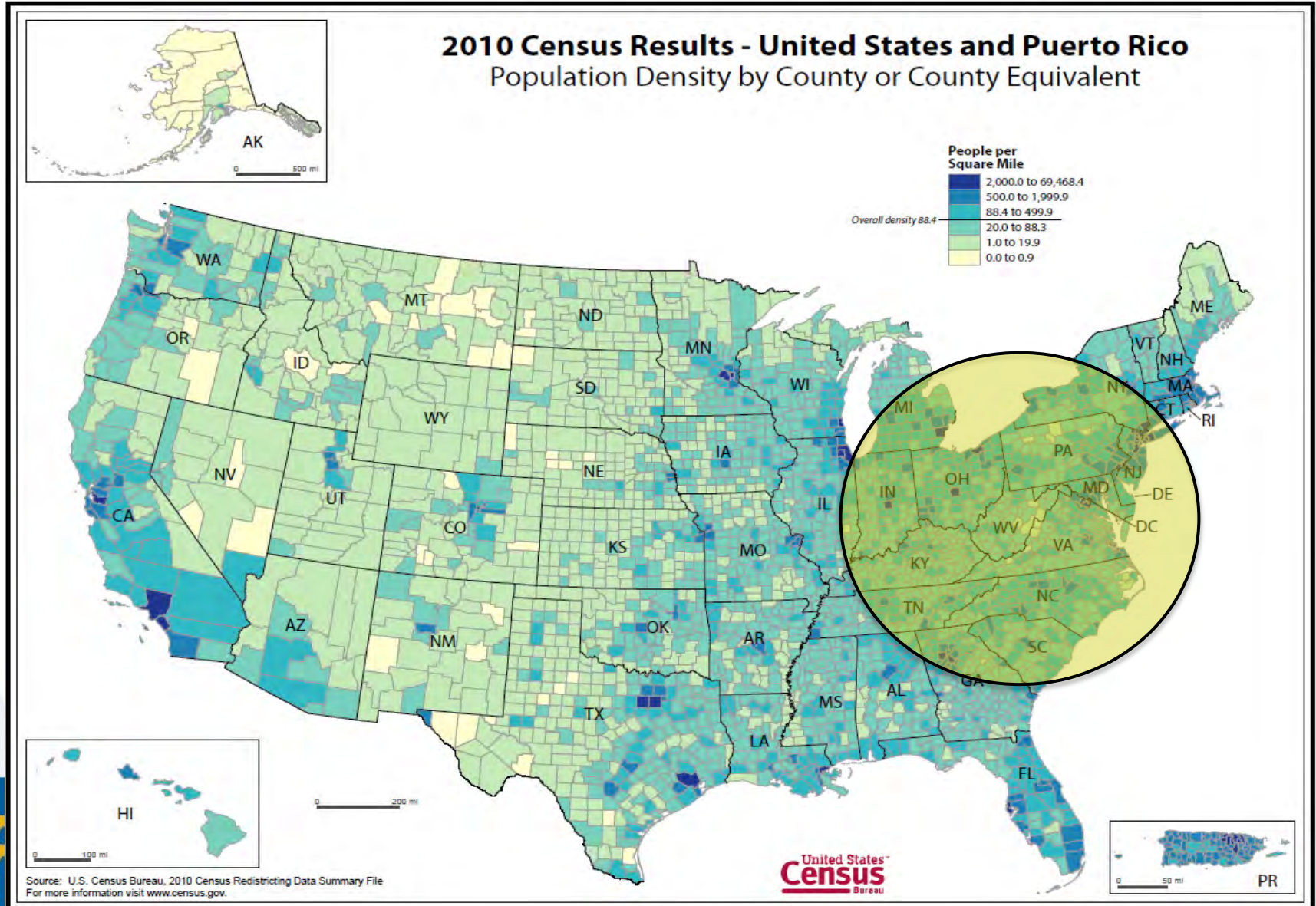


Regional Advantage

| Product | Price Unit | Gulf of Mexico | Europe | Asia | Appalachian Basin |
|----------------|------------|----------------|--------|------|-------------------|
| natural gas | \$/MMBtu | 2.50 | 6.30 | 8.20 | 0.87 |
| ethane | \$/gal | 0.19 | 0.49 | 0.60 | 0.04 |
| propane | \$/gal | 0.41 | 0.72 | 0.87 | 0.10 |
| isobutane | \$/gal | 0.66 | 0.64 | 0.93 | 0.40 |
| n-butane | \$/gal | 0.66 | 0.64 | 0.93 | 0.25 |
| gas condensate | \$/gal | 1.06 | 1.25 | | 0.90 |



Central Appalachia Is Key to Over 50% of the US Population



Chemical and Other Manufacturing from Marcellus Shale



POTENTIAL ECONOMIC IMPACTS OF CHEMICAL AND PLASTICS MANUFACTURING IN APPALACHIA

Martha Gilchrist Moore, Sr. Director – Policy Analysis and Economics

The Scenario and Opportunity

- 350,000-400,000 bpd ethane by 2025
- \$35.8 billion in new investment
- 5 ethane crackers + other facilities
- **Storage and pipeline infrastructure built**

Four-State Economic Impact

- 25,664 Direct Jobs
- 100,818 Total Jobs
- \$6.2 Billion Total Payroll
- \$2.9 Billion Taxes



Appalachian Basin NGL Storage Study

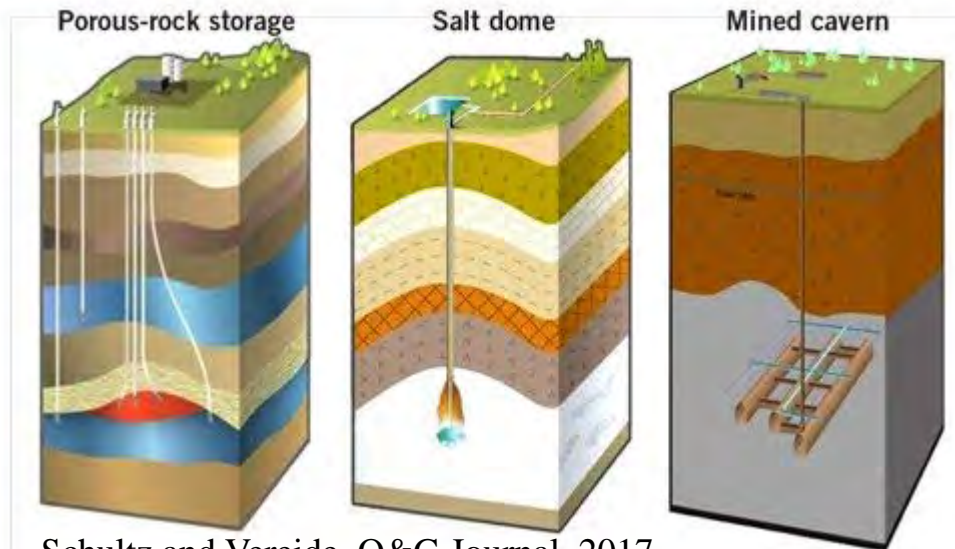
- Geologic investigation of subsurface storage potential for NGLs in a broad geographic area
- Study area is along the Ohio River, from PA to southern WV and eastern KY
- Project is a critical step in the process of infrastructure development
- Subsurface storage facilities with adjacent
- Surface NGL transportation
- Goal of this project: to provide essential data to support of the development the chemical manufacturing industry, promoting economic development



Types of Potential NGL Storage

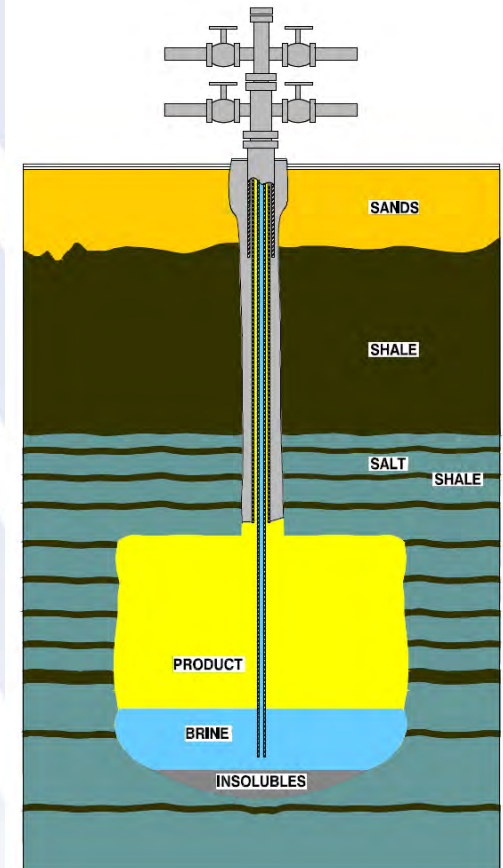
- Solution mining to create large cavities in Salina salt beds
- Subsurface excavation to create large mines in Greenbrier Limestone
- Injection into depleted gas fields with good porosity & permeability
- Vertical & lateral seals essential for each option

STORAGE TYPES



Schultz and Vereide, O&G Journal, 2017

FIG. 2



Schematic Illustration of a Solution-Mined Storage Cavern in Bedded Salt



The Appalachia Storage and Trading Hub

- January 3, 2018 Appalachia Development Group, LLC, (ADG) invited to submit a Part II Application for a loan guarantee under the U.S. Department of Energy (DOE) Title XVII Loan Guarantee Program.
 - The invitation for the Part II application is for a \$1.9 billion loan guarantee from the DOE to support the development of infrastructure for the Appalachia Storage & Trading Hub (ASTH).
 - ADG submitted Part I application on September 13, 2017 and working to secure a \$1.4 billion equity position.



Risks and Opportunities

- Environmental Oversight
- Severance/Resource Revenues
- Workforce Development and Entrepreneurship



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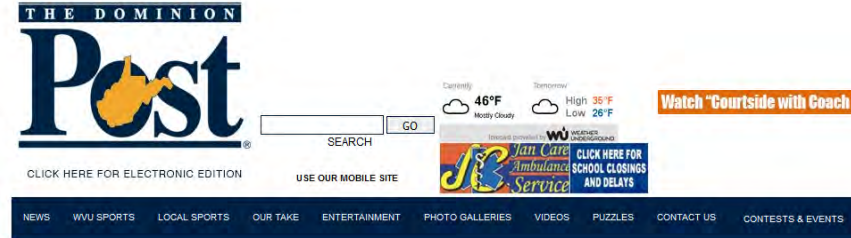
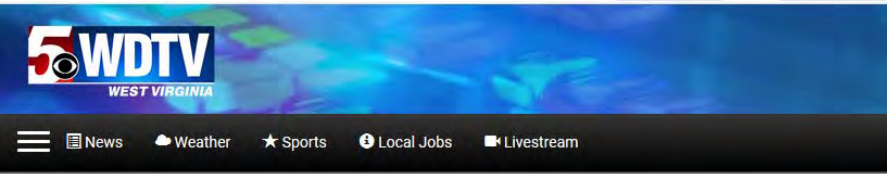


Environmental Oversight & Revenue

- Even with adequate laws, there must be credible enforcement (are the laws adequate?)
 - ~20 DEP Inspectors, ~55,000 active oil and gas wells
 - Historically, this is an area that the state has struggled to adequately regulate
 - Failure to address these issues in a substantive way looks like “business as usual” – which has historically not been a good outcome for WV
- Incentive programs and site redevelopment requires funding
 - Consider severance taxes tied to price – we need demand pull to bring up the price



China Energy Investment – How Did We Get Here?



Home / State / Article

\$83.7 billion China Energy investment boosts West Virginia, WVU on world stage

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WVU Energy Institute director lauds 'biggest single investment'

By Andrea Lannom | CNHI Statehouse Reporter Nov 10, 2017

CHINA BUSINESS EXCH



State, China Energy sign \$83.7 billion memorandum

West Virginia and China Energy have signed a memorandum of understanding announcing a plan in which China Energy would invest \$83.7 billion in...

Credit: MGN

Facebook Twitter Google+ LinkedIn Pinterest Email

The director of West Virginia University's Energy Institute called a memorandum of understanding signed Thursday between the Mountain State and China the "biggest single investment in the history of the state."

Brian Anderson, who also is a chemical engineering professor at WVU, said the state has been a partner with the Shenhua Group, a state-owned coal mining company that recently merged with another energy producer into China Energy, in researching coal liquefaction.

Anderson said he thinks the agreement, if finalized, could potentially have a big economic effect on the state.

State Commerce Secretary H. Wood Thrasher and China Energy President Ling Wen

signed the MOU Thursday afternoon in Beijing (just after midnight here), joined by President Donald Trump and Chinese President Xi

...y stage escalated Nov. 9 as China Energy as and a long-time research and development lition to the state.

...and other state officials to help coordinate the Storage and Trading Hub.

...erson, director of WVU's Energy Institute, said, ...st in our state through joint research, business West Virginia forward by expanding and

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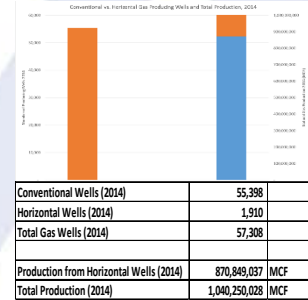
wdtv.com
dominionpost.com
Timeswv.com



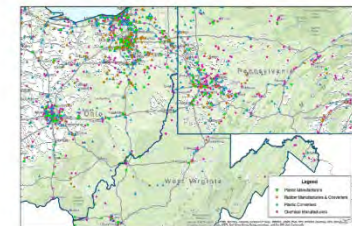
The WVU Energy Institute | energy

Several Factors Aligning At The Same Time

- Technological Change in Natural Gas Production
- Long Term Relationships With China
- Opportunity for Making US Production and Exports More Resilient



Petrochemical & Downstream Manufacturers within 400 Miles: 17,477 Companies



Chemical Manufacturers (purple): 8,371 Companies
 Plastic Converters (blue): 8,147 Companies
 Rubber Mfg. & Conv. (brown): 1,312 Companies
 Plastics Mfg. (green): 1,147 Companies



CEIC Deal – What It Is, What It Isn't

(and what hasn't been decided yet)

What it is:

- \$83.7B in total POSSIBLE investment over 20 years.
- Focus on buildout of technologies and infrastructure
- Natural Gas Power Gen, Investment in Storage
- Later plans for fractionation and downstream processing

Reflects Chinese intent for global footprint, including FDI

What it isn't:

- Natural gas export (more on this in a second)

What hasn't been decided yet:

- Specifics (specific siting decisions, specific partnering decisions – too early in the decision process)

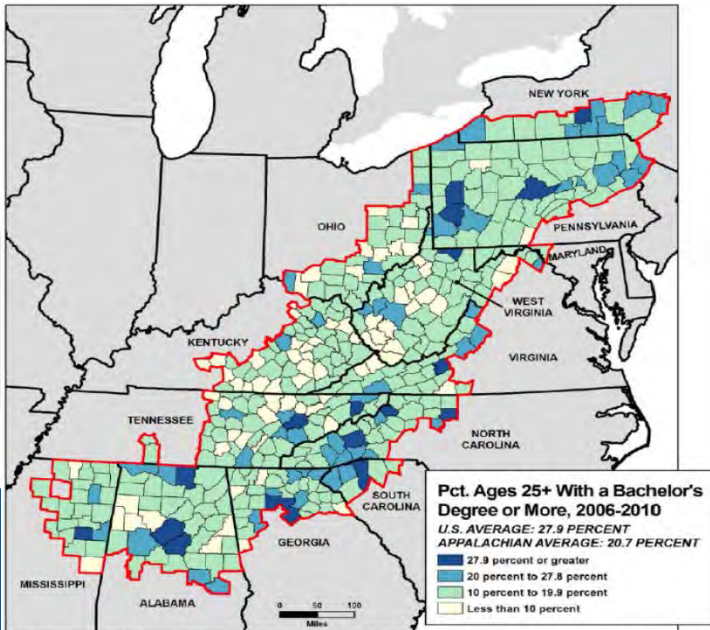


Workforce Development and Entrepreneurship

- The “biggest bang” outcome is going all the way up the value chain with WV BASED companies
- Understanding that “entrepreneurship” occurs all across the sector!
 - Innovations in environmental technology are just as valuable as innovations in production or conversion technology

Higher Ed Attainment Directly Relates to Innovation

- 23% of working age population had a bachelors degree of more (7% less than US average)
- New Inventions, Patents, Development of New Sectors
- Labor Force to Support Innovative Industries



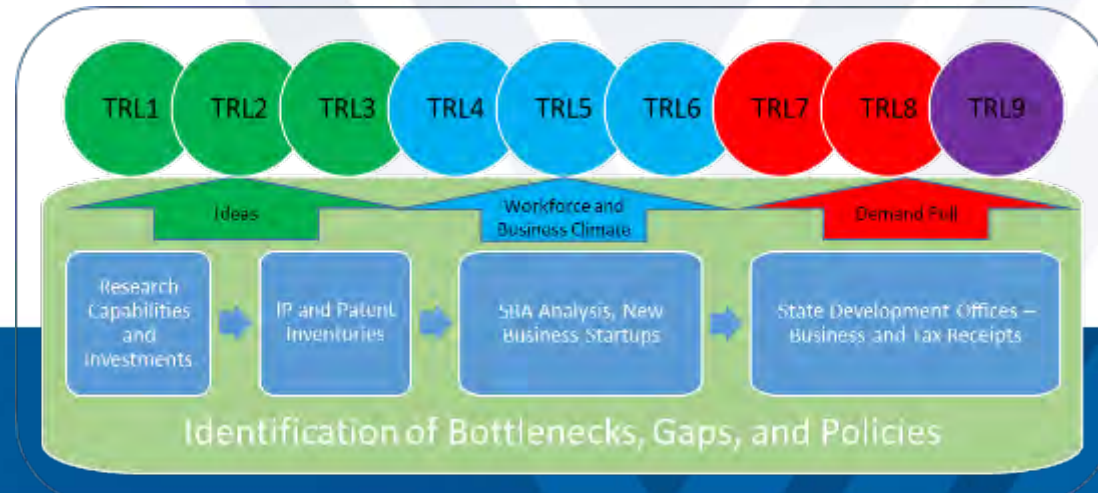
Map Title: Percent of Persons Ages 25 and Over in the Appalachian Region With a Bachelor's Degree or More, 2006-2010
 Data Source: U.S. Census Bureau, 2006-2010 American Community Survey.

What Are Our Barriers?

- Labor Force Training
- Educational Attainment
- Financing (and how this relates to entrepreneurship)
- Regional Perceptions
- Time Scales for Commercialization

What Are Our Advantages?

- Labor Force Availability
- Geography
- Resource Availability
- IP
- Development/Research Capability





The WVU Energy Institute

The Institute's mission is to coordinate and promote University-wide energy research in engineering, science, technology, and policy.

With an emphasis on

Fossil Energy

Coal, Oil, and Natural Gas

Sustainable Energy

Biomass, Geothermal, Wind, and Solar

Energy Policy

Energy and Environmental Policy

Environmental Stewardship

Protecting our Air and Water Resources



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