Breakthroughs in Unconventional Hydrocarbons: Opportunities for Natural Gas Utilization

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WEST VIRGINIA MANUFACTURERS ASSOCIATION

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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

2025 Goals

(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

Energy Institute Initiatives

Research

- Fossil
  - Coal, gas, oil
- Renewable
  - Biomass, solar
- Policy
  - Economic, regulatory
- Environment
  - Water, air

Education

- Energy graduate programs
- Energy minor and certificate programs
- General Education Curriculum
- Student energy club

Campus Sustainability

- Building efficiency
- Transportation services
- Campus energy services
- Student learning opportunities

Broad Areas of Energy Research

- **Fossil Energy**: Promote the efficient use of fossil resources, conversion, extraction, utilization, and environmental management

- **Energy Policy**: Analyze energy policies, and their impact on use of these resources, carbon management, environmental, and infrastructure

- **Sustainable Energy**: Promote energy efficiency, alternative fuels, conservation, renewable energy sources, geothermal, and sustainable and responsible development

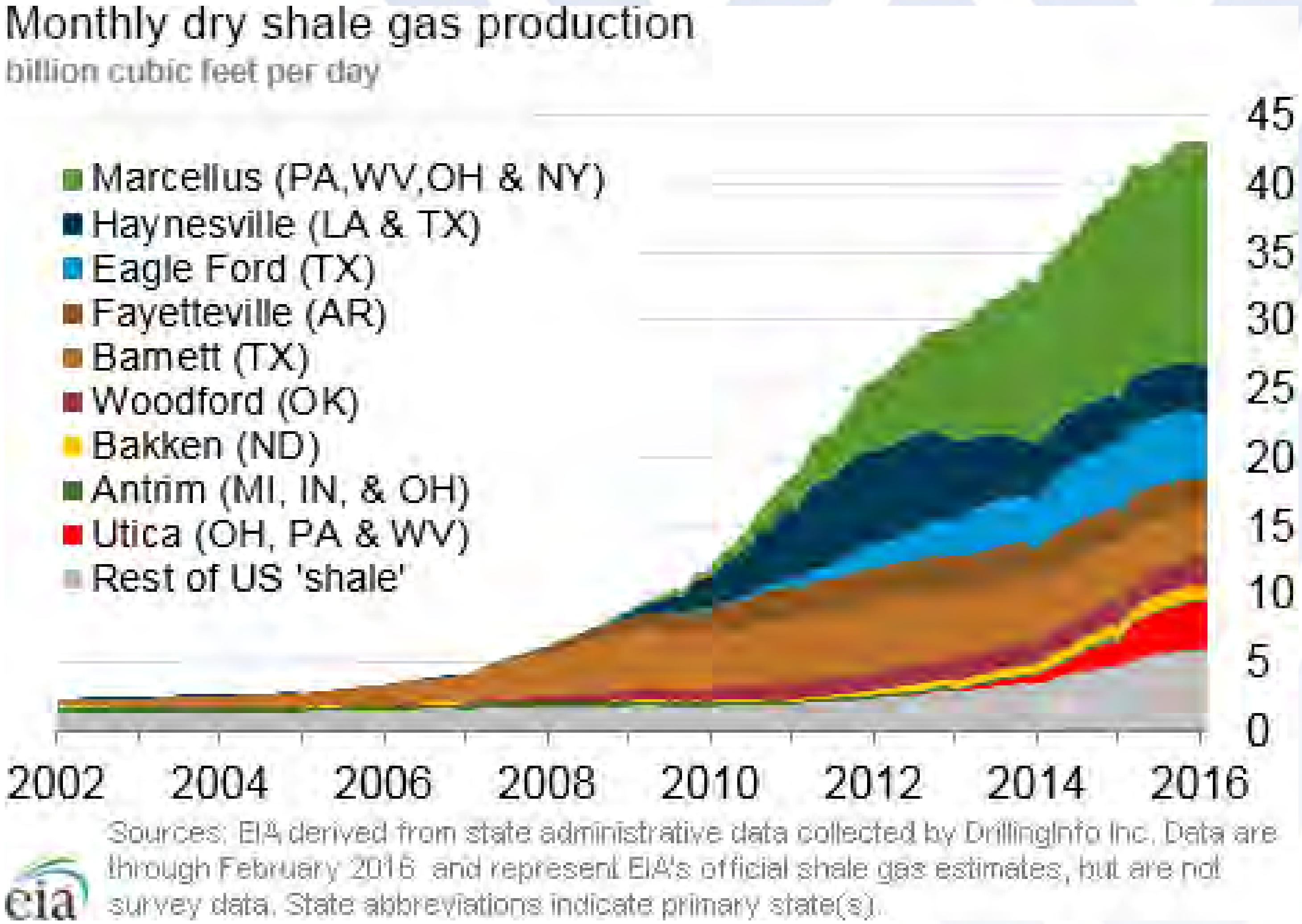
- **Environmental Stewardship**: Ensuring that energy production is balanced with minimizing negative impacts to our air and water resources

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
- **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

Marcellus (and Utica) are driving U.S. Gas production



Natural gas utilization

The focus is on responsible demand-side research that emphasizes the technology needs to promote responsible growth of the shale gas industry and economic development in the State.

The focus must include economic, legal, and policy needs to inform the State and legislative decision makers.

The emergence of significant national natural gas plays, coupled with thermocatalyic pathways, provides the potential to decrease dependence on conventional petrochemical routes towards a variety of products, including gasoline, diesel, methanol, ethanol, ammonia, hydrogen, and a variety of oligomers and polymers.

Natural gas utilization at WVU

- Topic areas
  - Gas to liquids (GTL)
    - Catalytic approaches
    - Non-catalytic approaches
  - Direct-use NG fuel cells (FC)
  - NG combustion (NGC)
    - Stationary
    - Vehicular
  - Gas to chemicals (CTC)
    - Alkanes
    - Aromatics

- Basic science needs
  - Catalyst and chemical pathway development (GTL, GTC)
  - Fundamental SOFC material development (FC)
  - Reactive CFD modeling (NGC, FC)
  - Computational chemistry (GTL,GTC,NGC,FC)

WVU Mountain of Excellence in Shale Gas - Opportunities

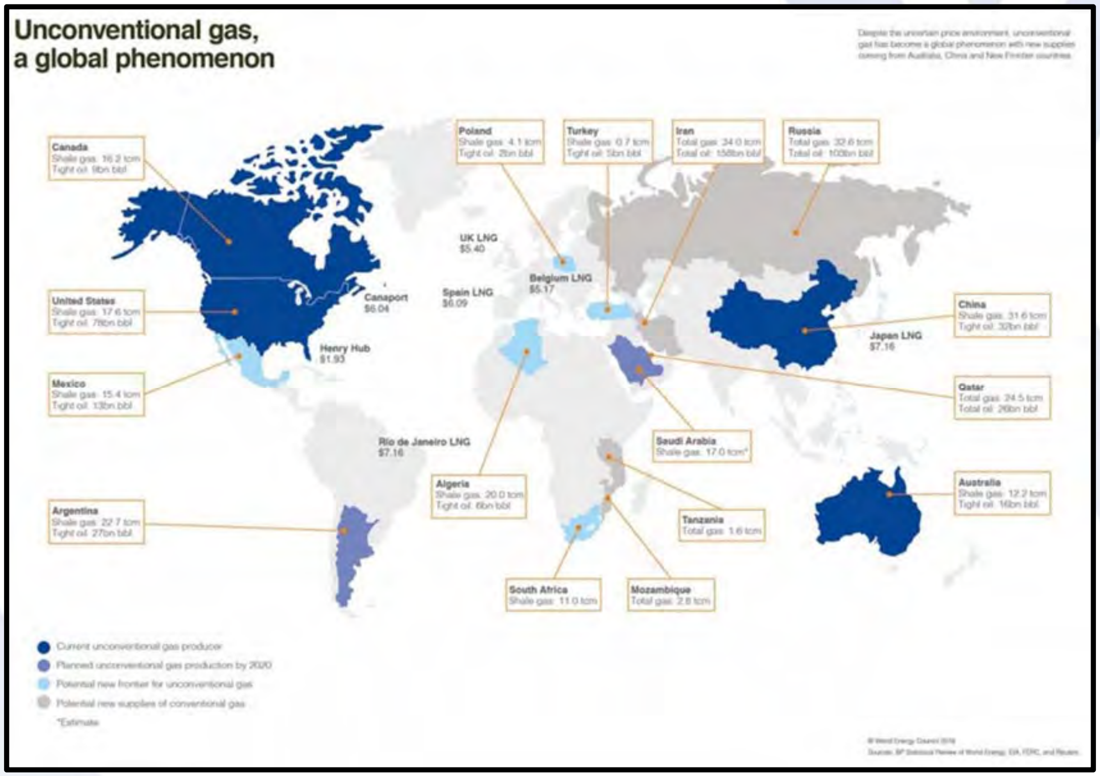
- **WV – a long history in NG to chemicals**
  - Clendenin, WV: Site of the world's first commercial ethylene plant

- **Upstream:**
  - resource evaluation,
  - management, and
  - production
- **Downstream:**
  - use as an alternative transportation fuel
  - conversion to liquid fuels or chemicals
  - use in fuel cells

- Union Carbide 10,000 lb/day ethylene plant online in 1921
- Driven by access to raw materials

International Forum on Unconventional Gas Sustainability and the Environment (INFUSE)

WVU in partnership with the US State Department, will increase foreign governments' understanding of issues and best practices related to sound unconventional gas sector management.



- The overall goal is to increase international understanding of how proper drilling, hydraulic fracturing and water management reduces environmental risks and leads to sustainable resource development.
- Beneficiary government officials will better understand the unique safety, environmental, and social challenges and best practices associated with the development of unconventional resources.

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Research Support Operations

MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY

MSEEL

MSEEL
Marcellus Shale Energy & Environment Laboratory
Northeast Natural Energy
West Virginia University

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

NATIONAL ENERGY TECHNOLOGY LABORATORY

northeast NATURAL ENERGY

THE OHIO STATE UNIVERSITY

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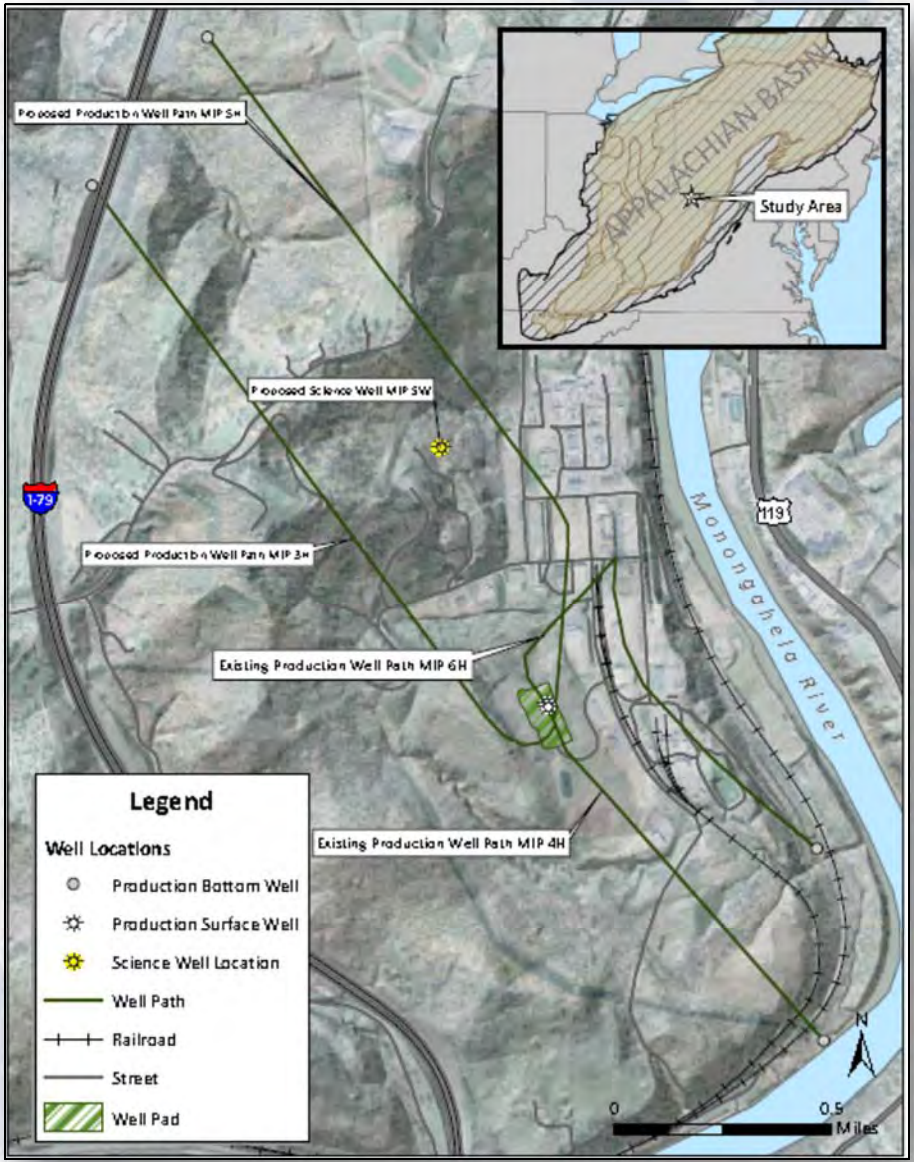
Phone: 304.293.9660
Email: tim.carr@mail.wvu.edu

MSEEL Vision

- Demonstrate the Best Practices to Drill, Complete and Produce a New Horizontal Well That Minimizes Any Environmental/Societal Costs While Maximizing Economic Productivity
- Monitor and Document Impacts in a Controlled Environment
    - Greenhouse Gas Emissions
    - Local Air Pollution
    - Water Supply and Quality
    - Noise and Activity
    - Societal Impacts
- Develop New Technologies to Maximize Production
    - Microseismic Monitoring
    - Production Monitoring
    - Advanced Logging
    - Simulation
- Develop New Scientific and Engineering Approaches to Apply to Multi-disciplinary and Multi-institutional Natural Resource Studies

MSEEL Site


Study Area
APPALACHIAN BASIN
Proposed Production Well Path MIP 5H
Proposed Science Well MIP SW
Proposed Production Well Path MIP 3H
Existing Production Well Path MIP 6H
Existing Production Well Path MIP 4H
Monongahela River
I-79
119
Legend
Well Locations
Production Bottom Well
Production Surface Well
Science Well Location
Well Path
Railroad
Street
Well Pad
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0.5
Miles
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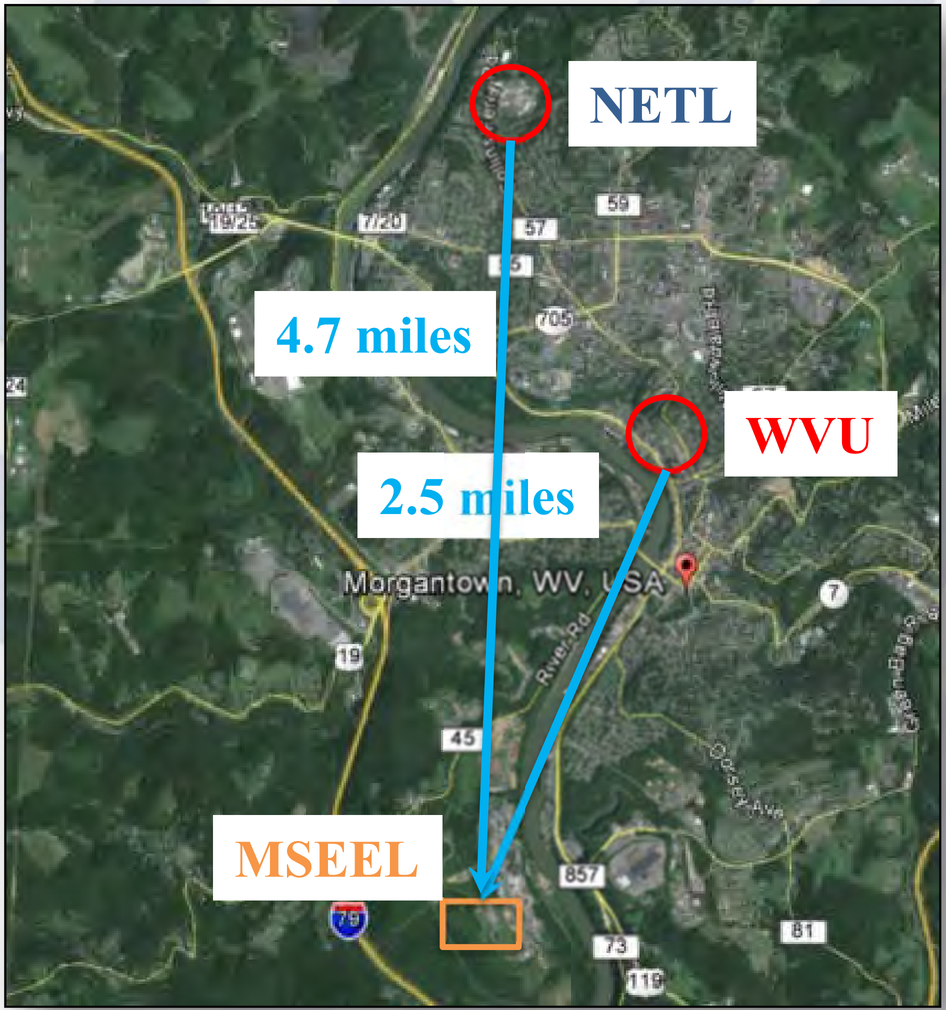
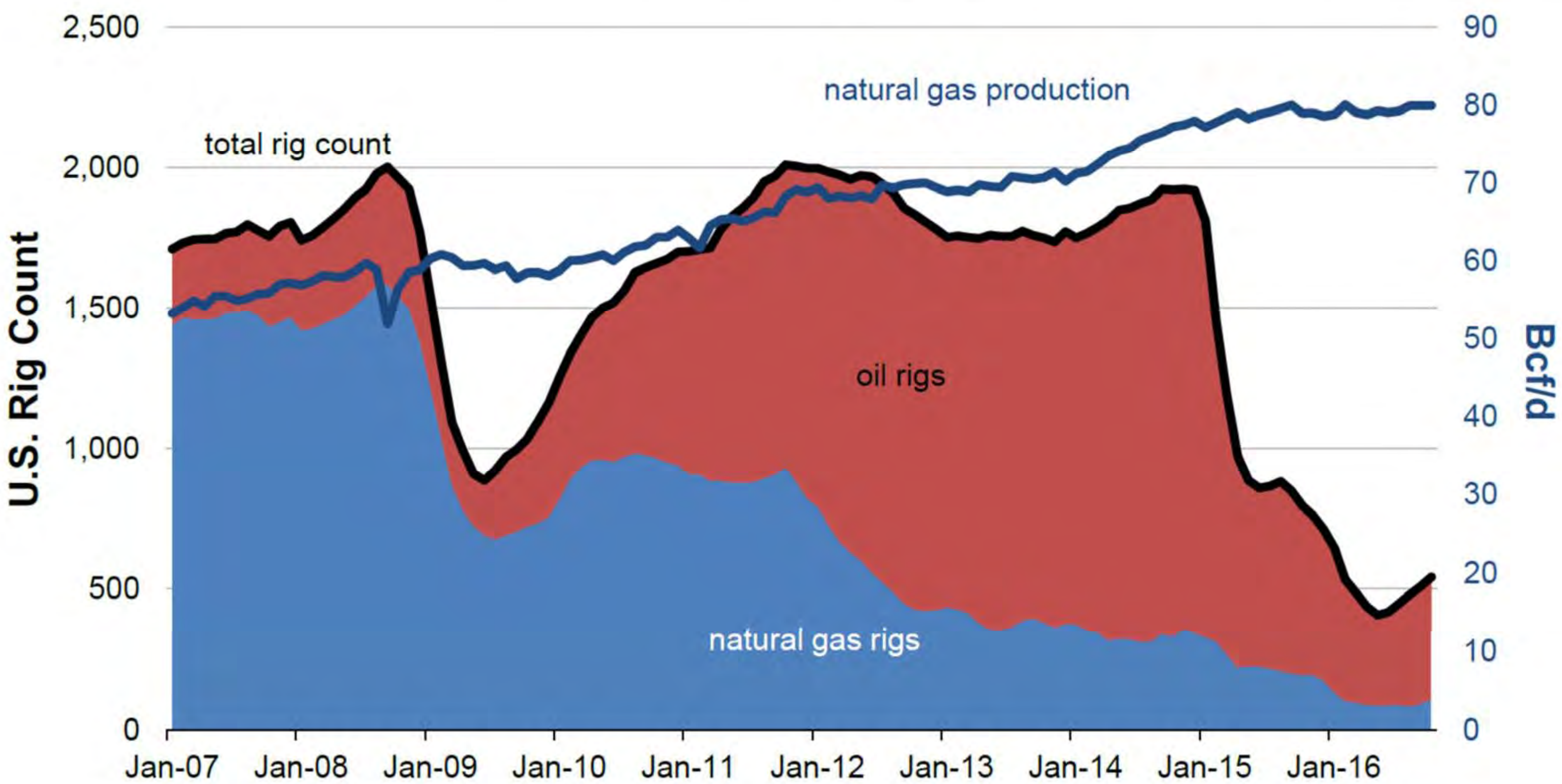
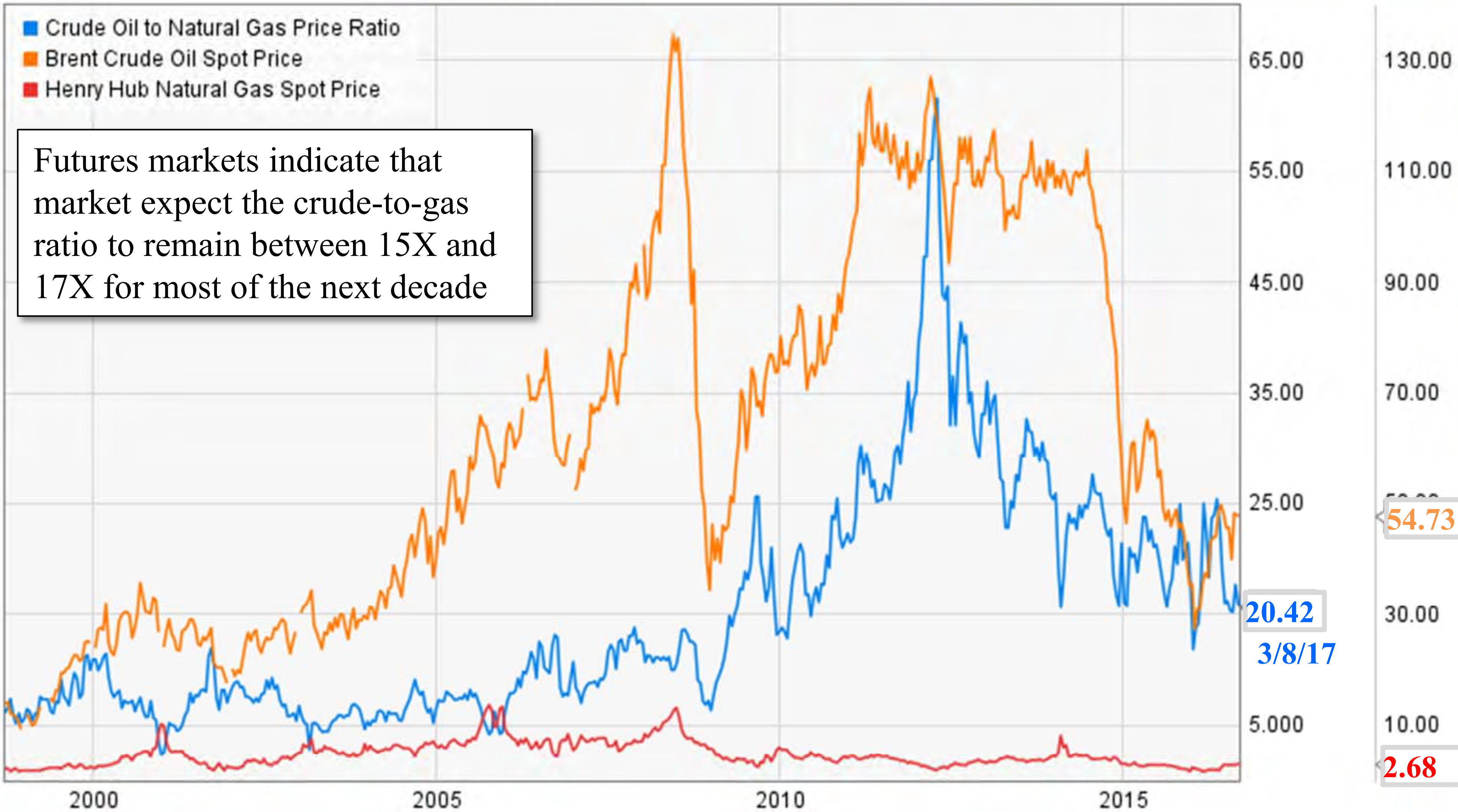

NETL
4.7 miles
WVU
2.5 miles
Morgantown, WV, USA
MSEEL
River Rd
Dorsey Ave

U.S. Rig Count and Production



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

Natural gas advantage

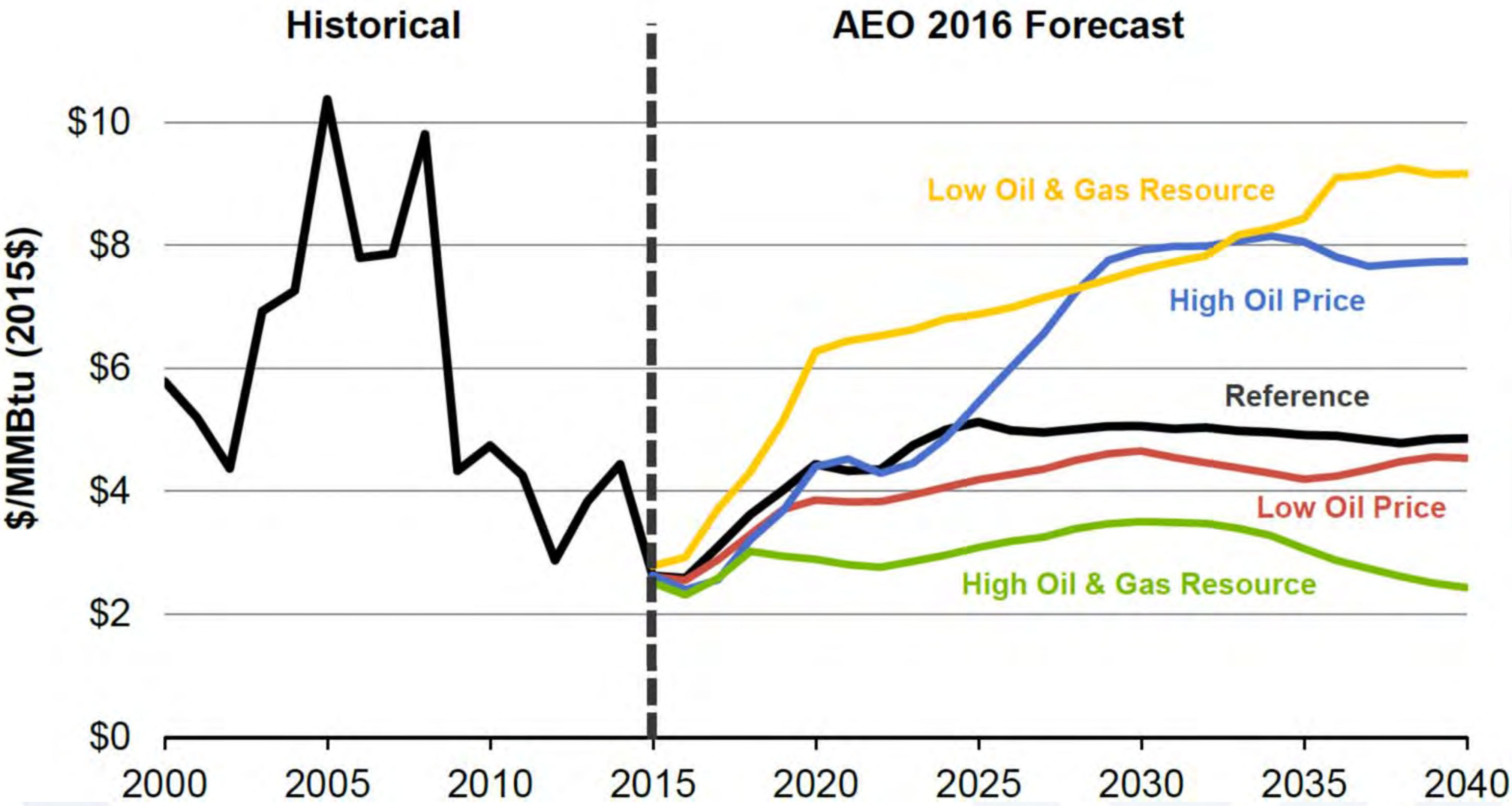


Source: EIA

The “true” BTU ratio of WTI crude to natural gas of 5.8 MMBtu/Bbl

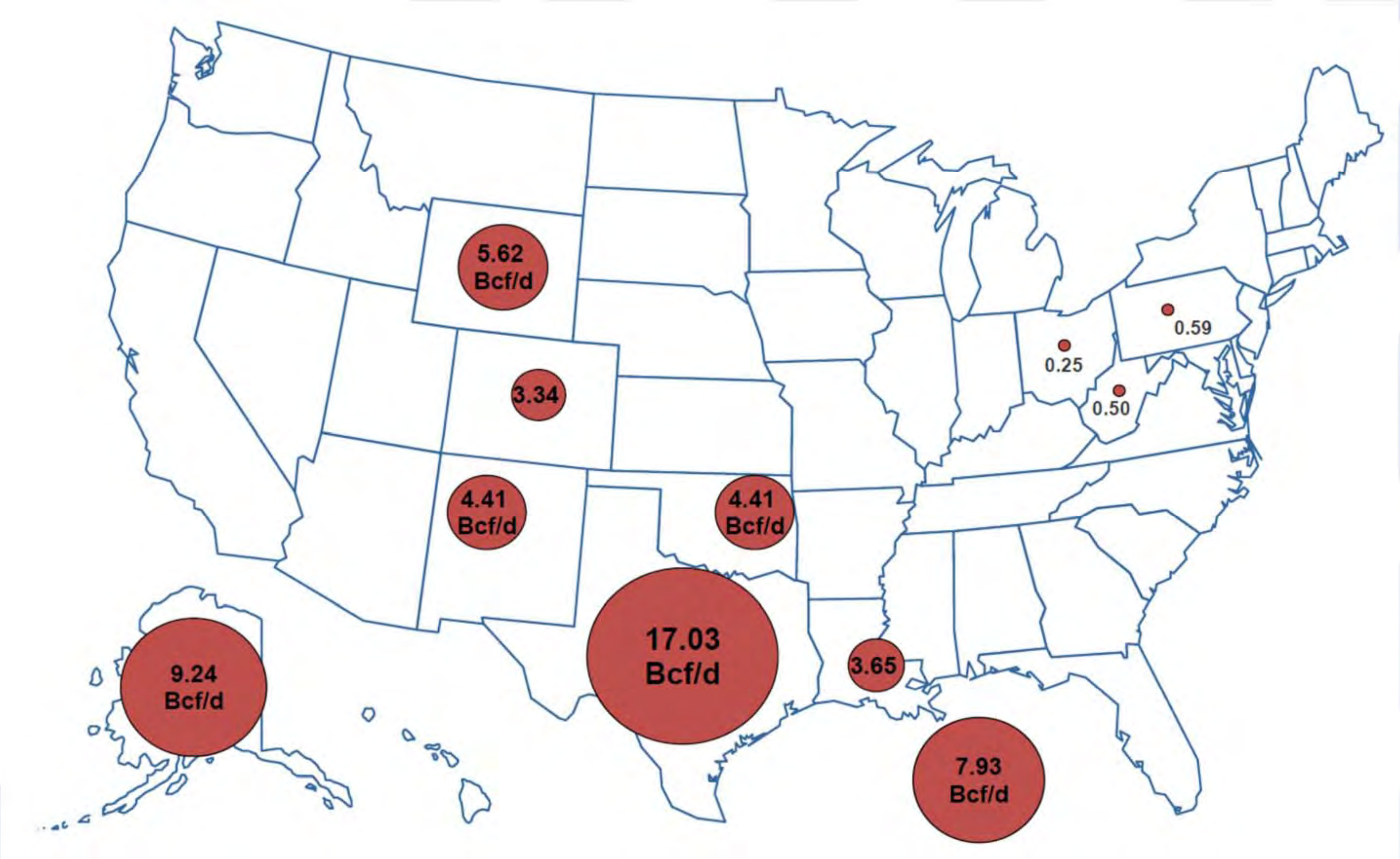
Natural Gas Prices –Various Cases

Henry Hub Spot Prices ($/MMBtu) Under Various EIA Cases



Natural Gas Production Shifts

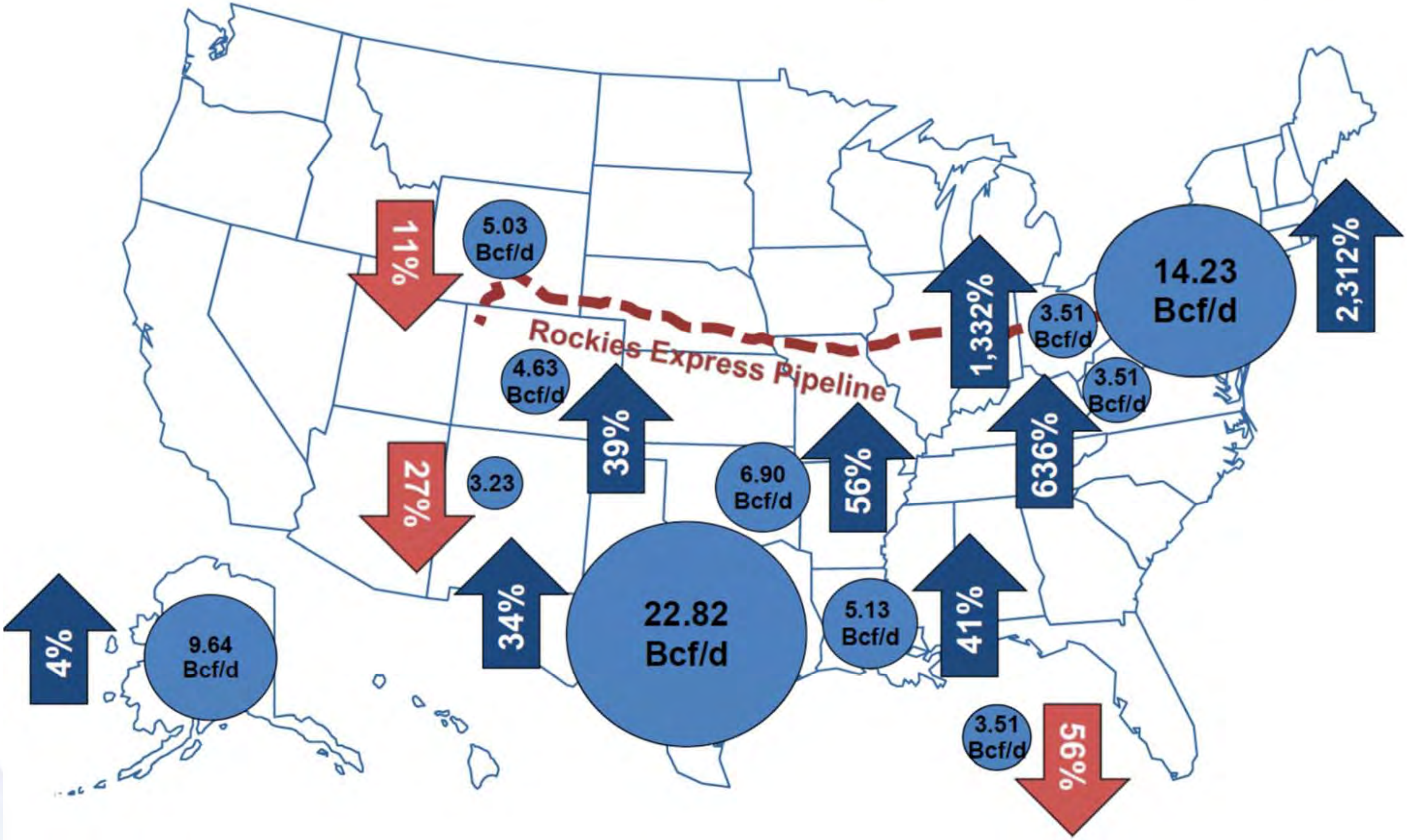
U.S. Natural Gas Production in Jan. 2006, Bcf/d



Source: EIA, Annual Energy Outlook 2012 and Monthly Natural Gas and Petroleum Report, July 31, 2012

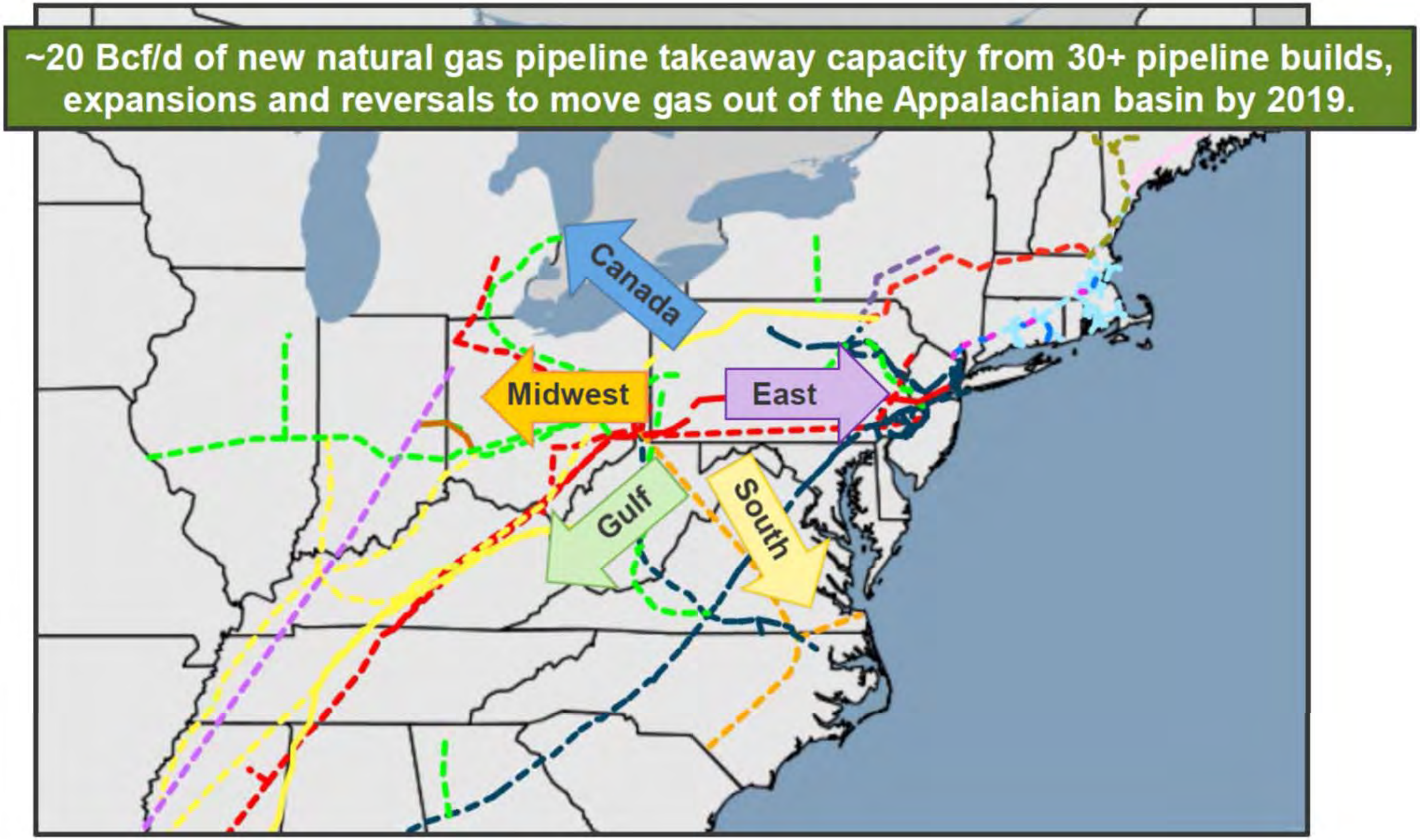
Natural Gas Production Shifts

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



Source: RBN Energy and EIA

Tri-State Shale Summit

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

Vision shared

Team neo

Allegheny Conference on Community Development

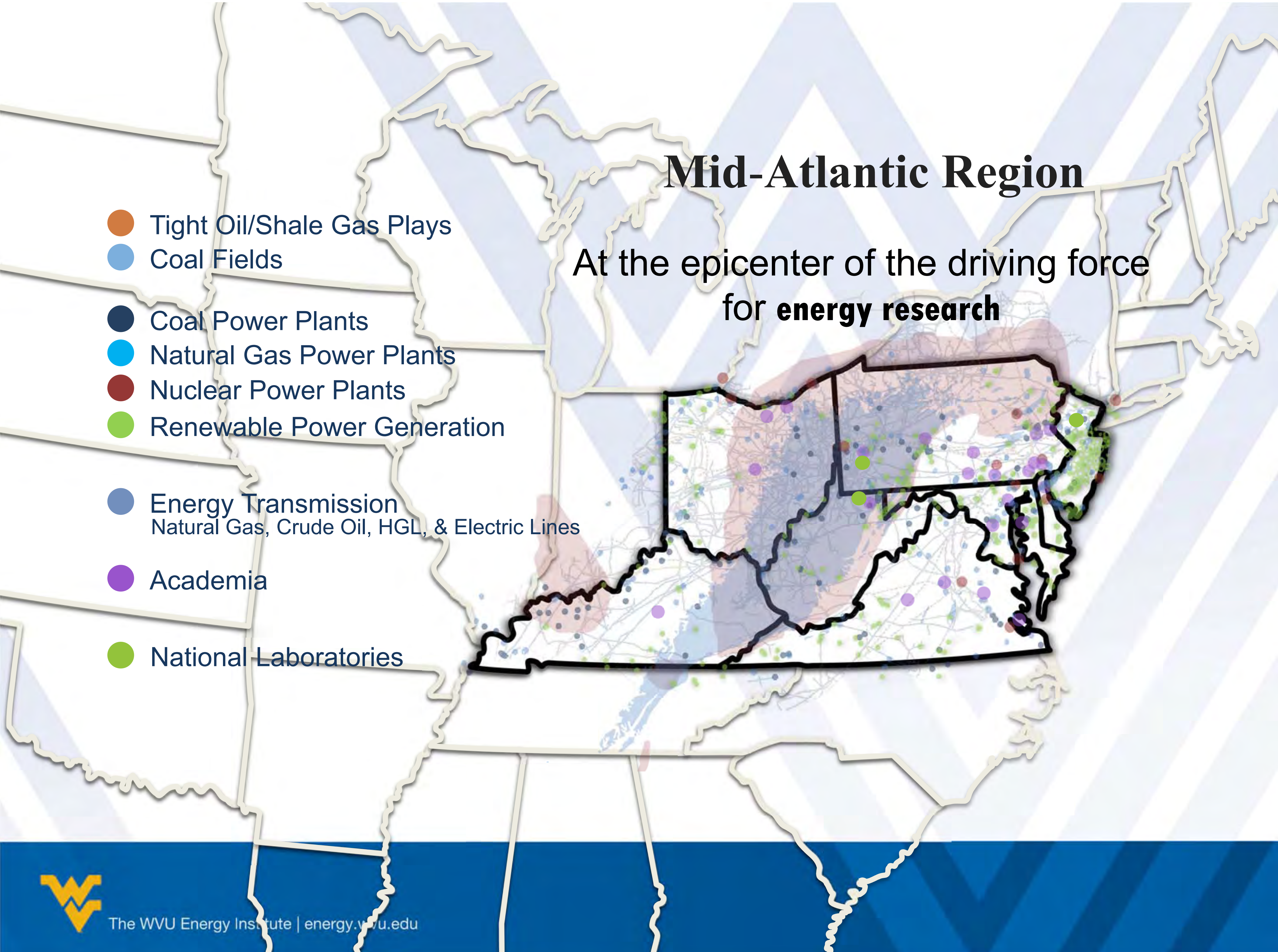
CLAUDE WORTHINGTON BENEDUM FOUNDATION

TRI-STATE SHALE SUMMIT

October 13, 2015

Mid-Atlantic Region

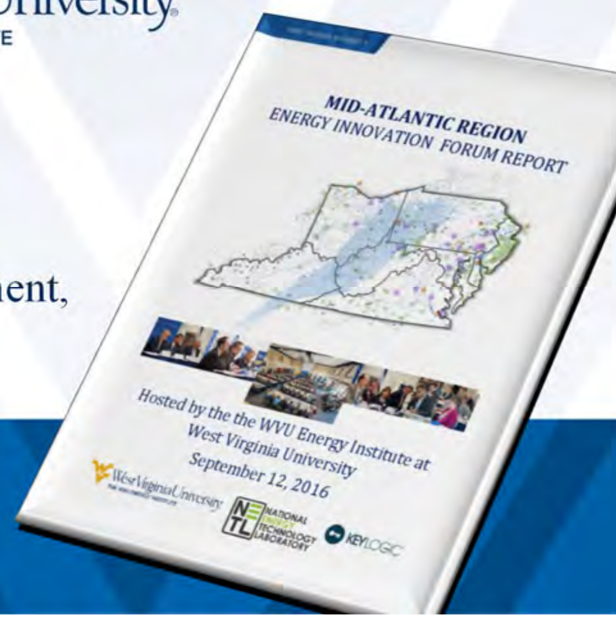
At the epicenter of the driving force for **energy research**



MID-ATLANTIC REGION ENERGY INNOVATION FORUM
HOSTED BY WEST VIRGINIA UNIVERSITY

SEPTEMBER 12, 2016
MORGANTOWN, WEST VIRGINIA

Areas of Focus: Sustainable Energy Portfolio Development, Academic-Industry-Government Partnerships



energy.wvu.edu/innovationforum

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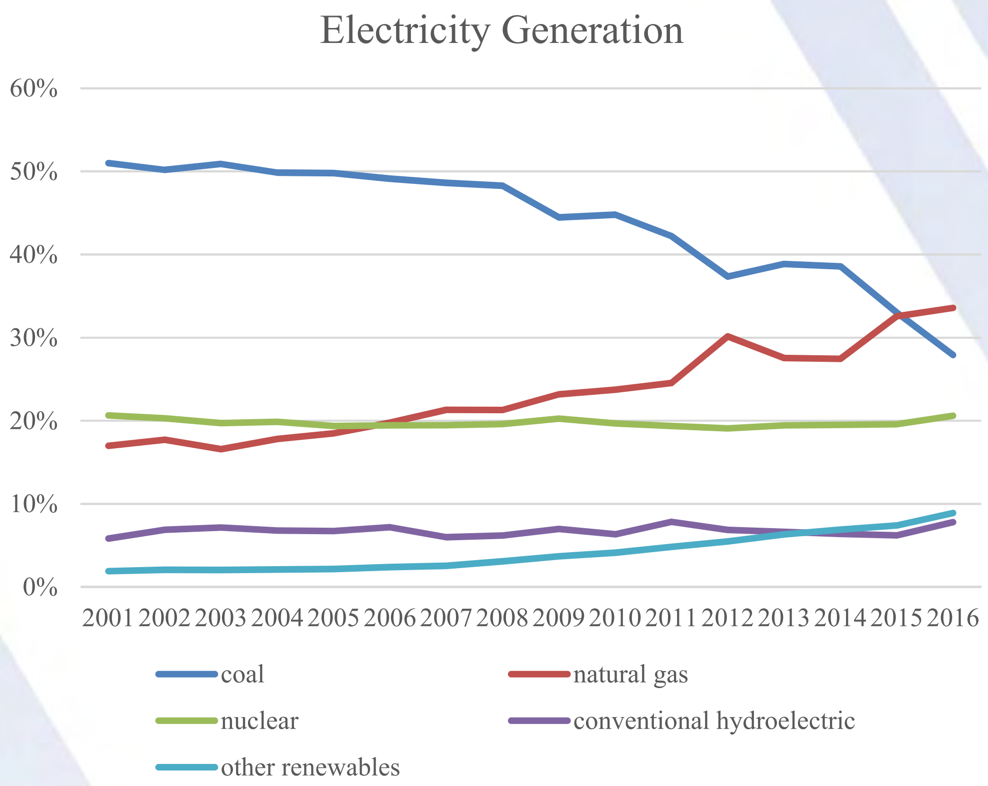
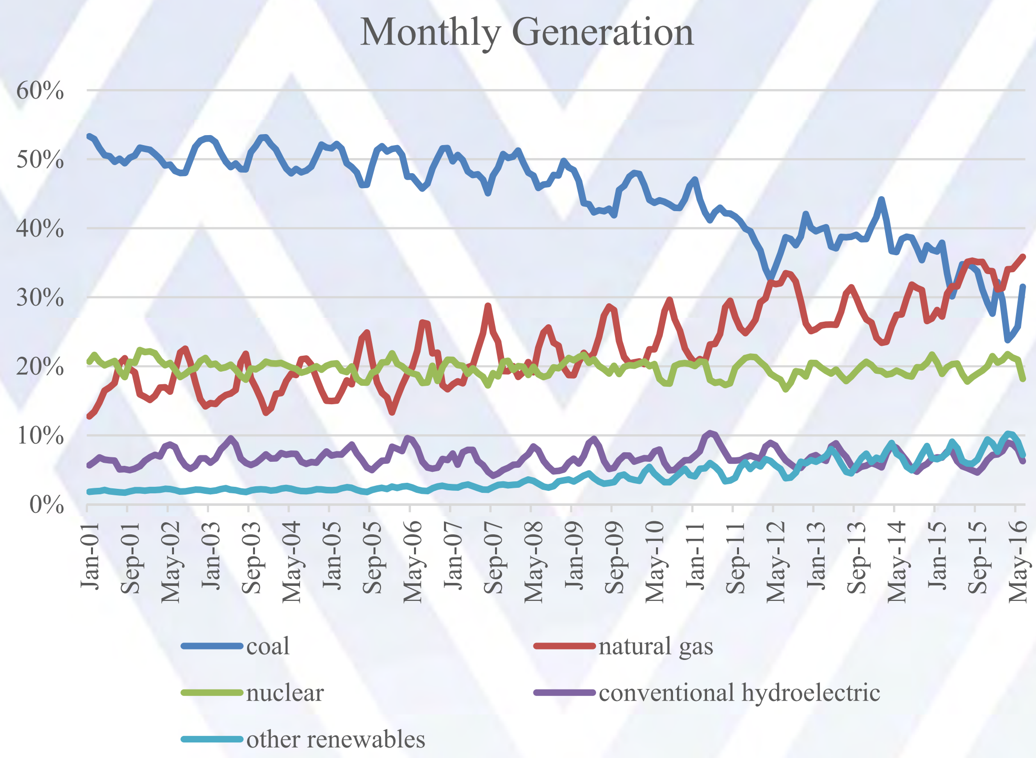
Major Takeaways: Mid-Atlantic Region Forum at WVU

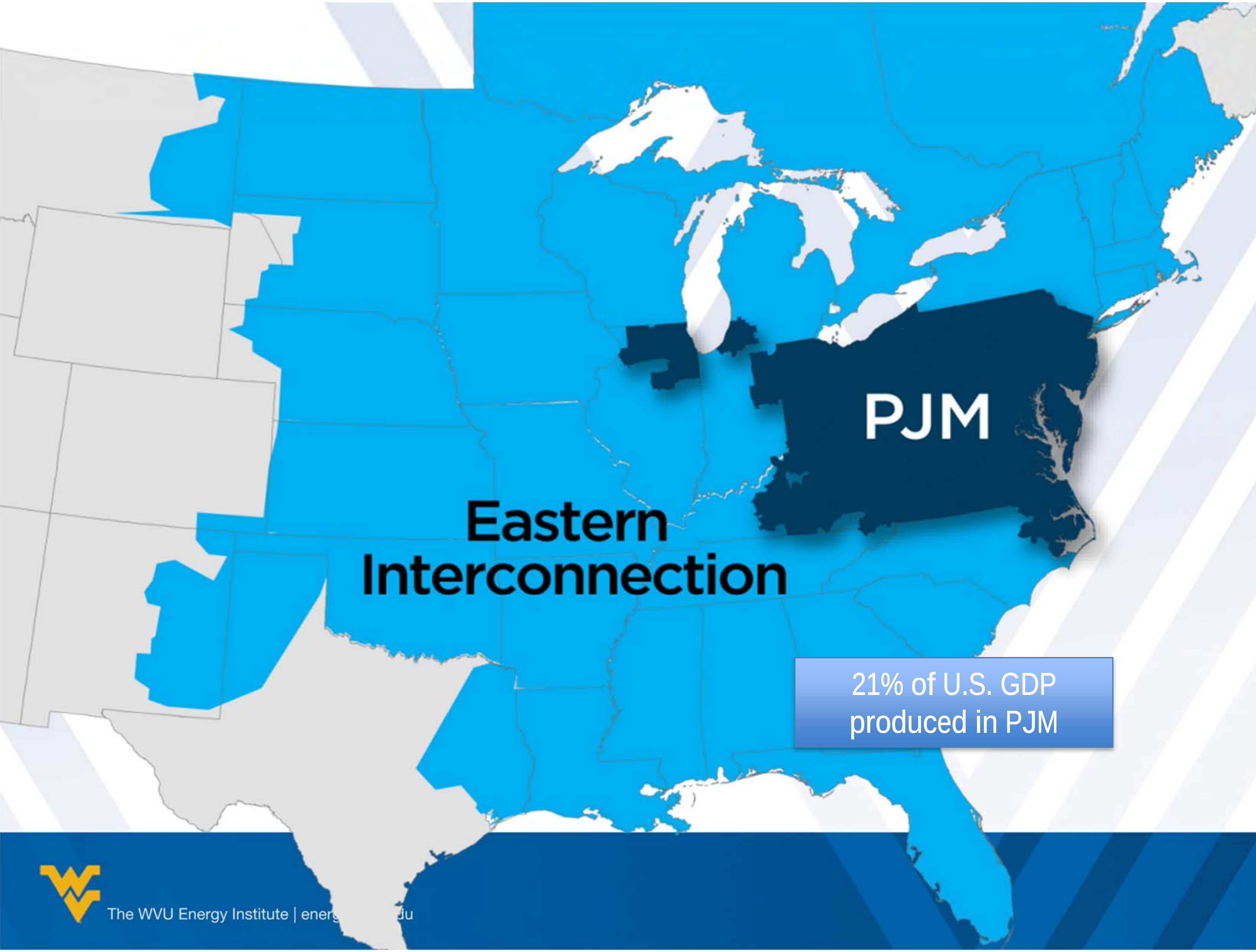
Key Takeaways

- **Opportunities**
  - Large (55 million ppl), diverse, energy-rich region with **engaged stakeholders from all sectors**
- **Priority Innovation Focus Areas**
  - **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)
- **Challenges**
  - **Funding** for large-scale demonstration of technologies - CCUS, power cycles, NG conversion demonstrations cost $100s of millions
  - Diverse region and **broad priority focus** areas
- **Next Steps**
  - **Five follow-on events** coordinated by the TrUE Alliance
    - **Grid**: EPIC Meeting Pittsburgh, 11/14-11/15; **Storage**: Center of Excellence in Ohio meeting on Energy Storage end of October in Cleveland;
    - **NG Utilization**: AIChE Natural Gas Utilization Workshop on November 1-3, 2016 in Morgantown and technical workshop Tri-State, November 30
    - **Efficiency**: CMU and Energy for the Power of 32
  - PJM Interconnect will be working with WVU on **regional planning and innovation efforts**
  - Coordinate with **sub-regional consortia** in developing a Mid-Atlantic Region Energy **Innovation Roadmap**

The Electricity Fuel Mix is Changing – Generation through Q2 2016

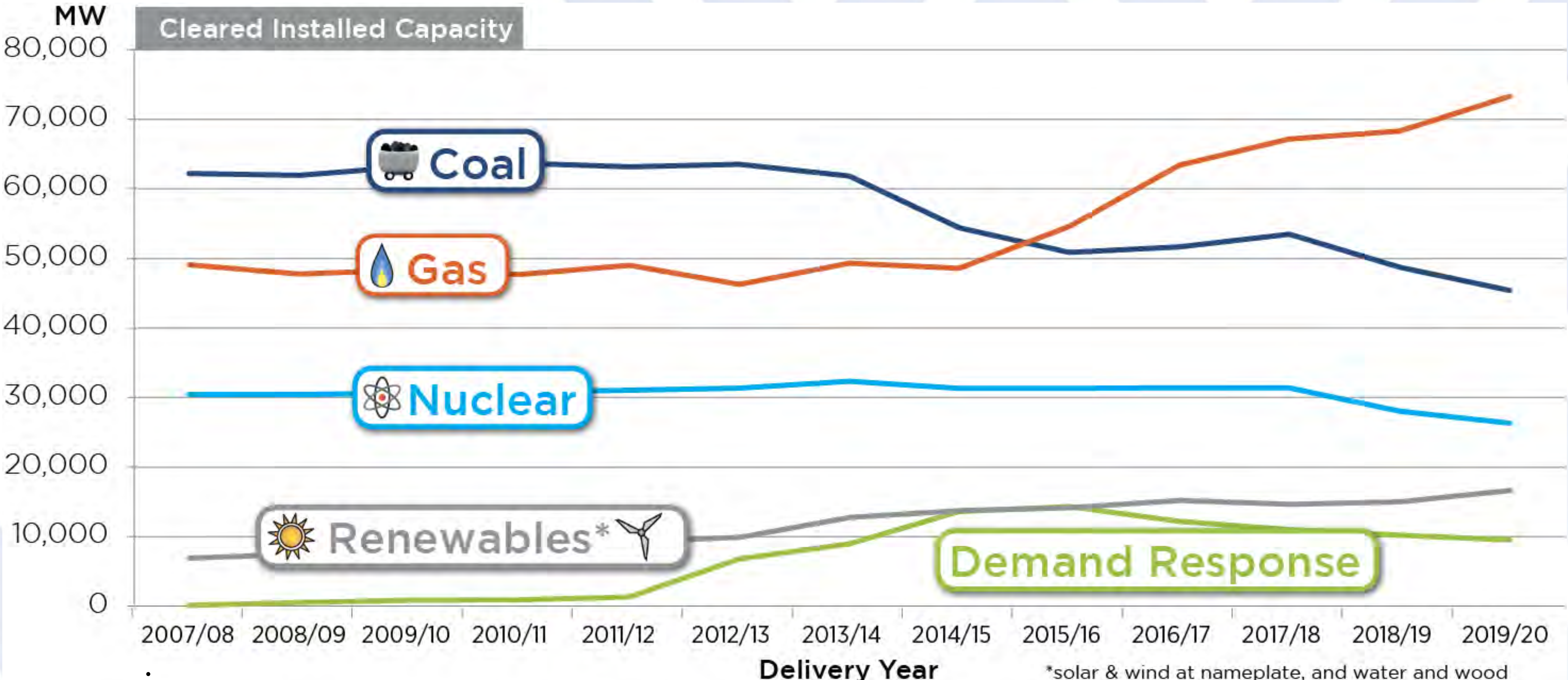






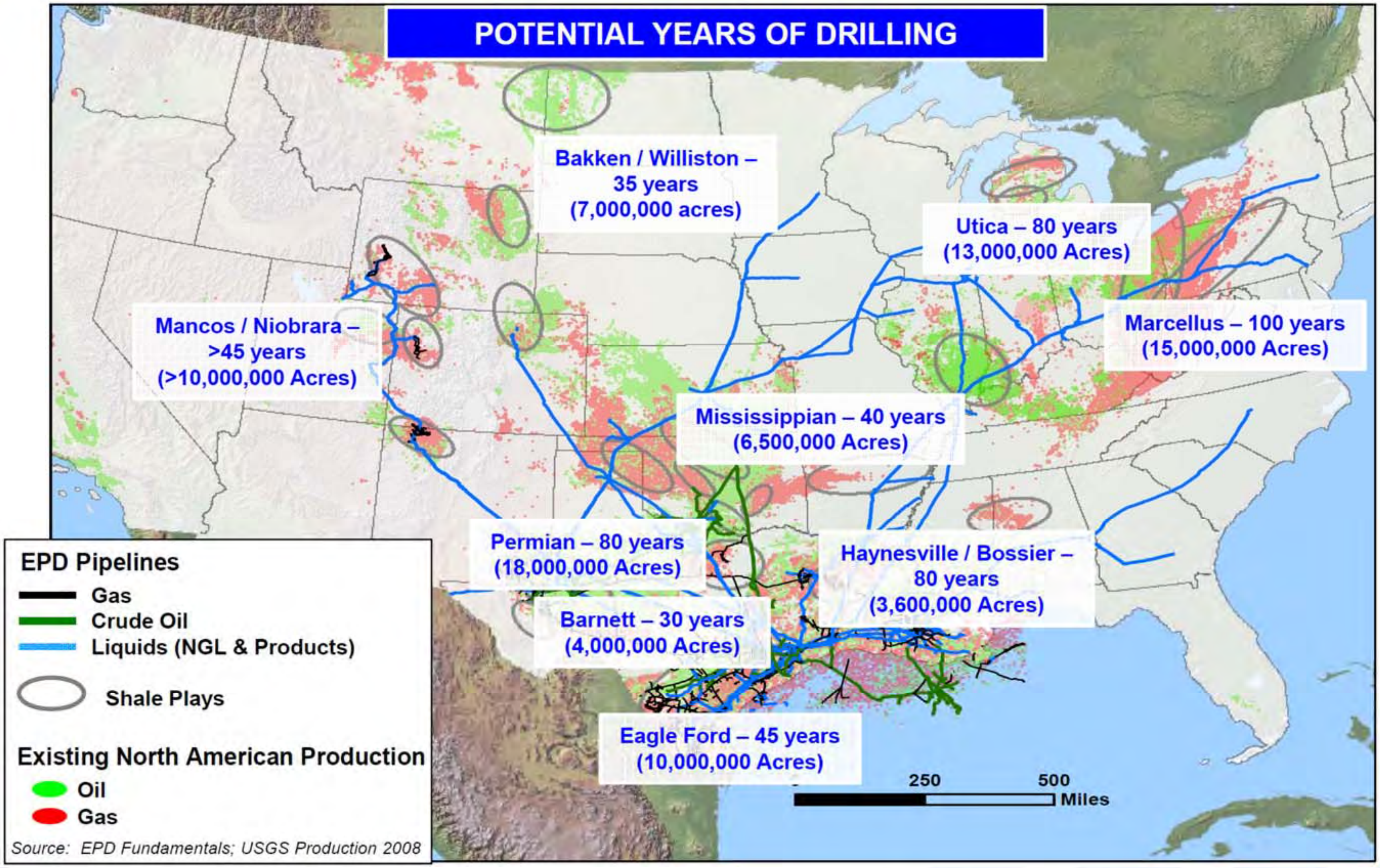
21% of U.S. GDP
produced in PJM

Capacity Market Managing Change

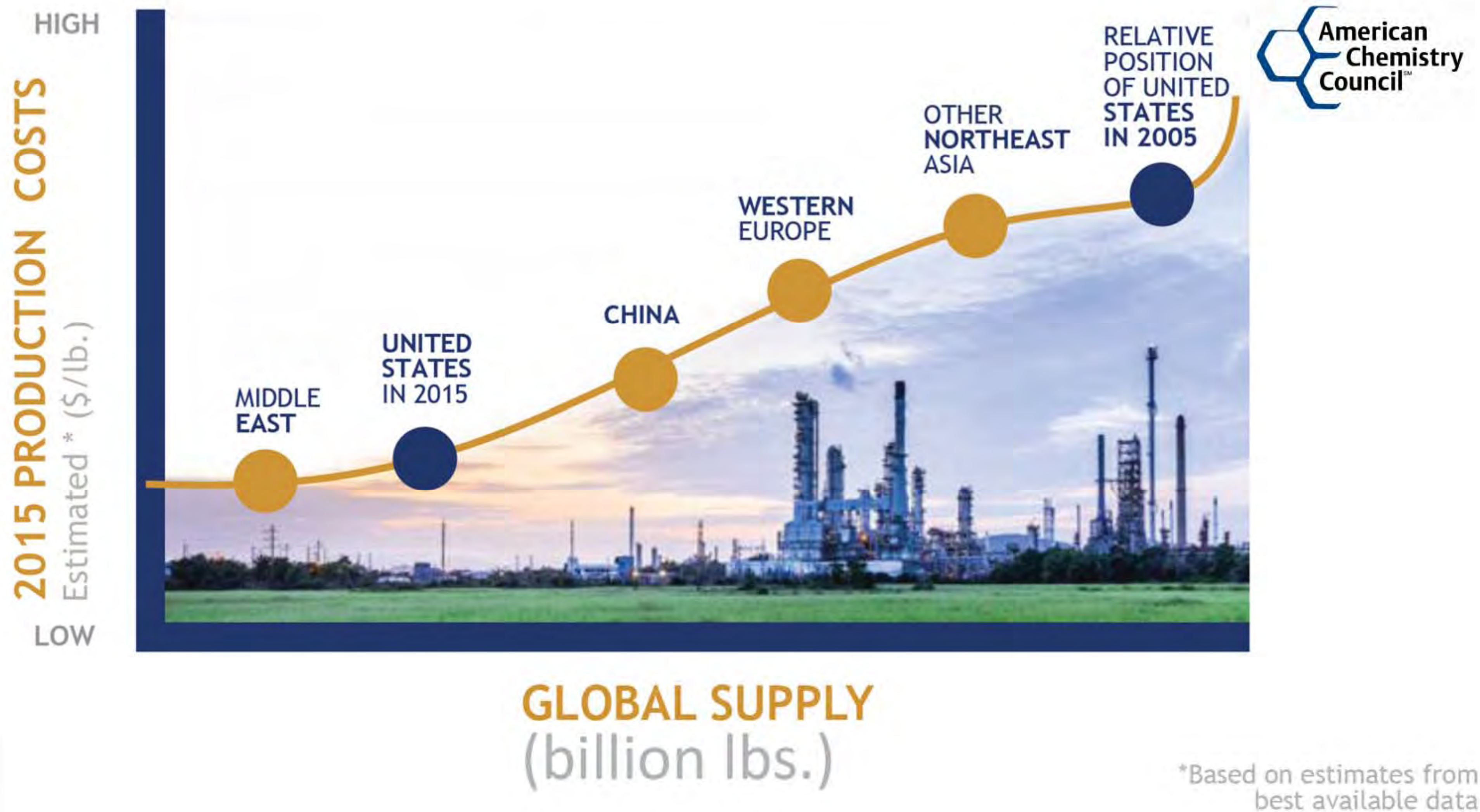


www.pjm.com

Potential lifetime of North American Gas



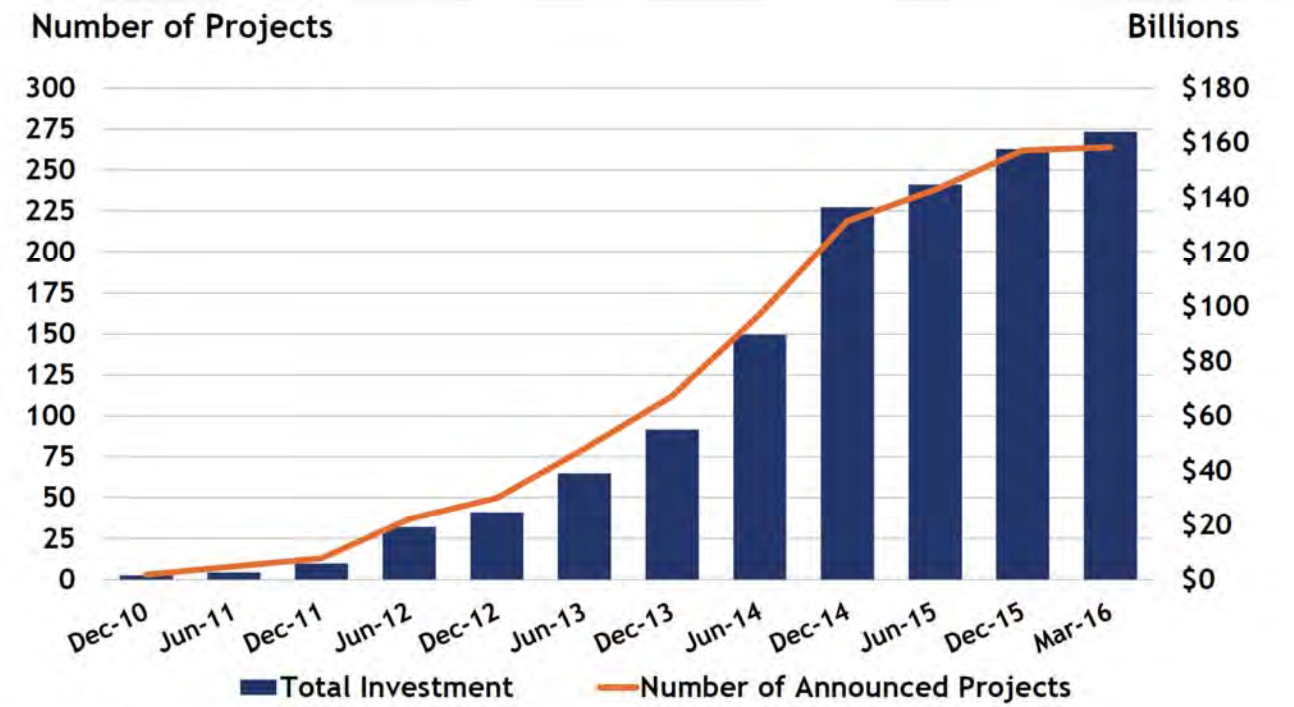
U.S. Petrochemical Production Costs



Source: American Chemistry Council, 2016

Impact of Shale Production on the Chemical Industry

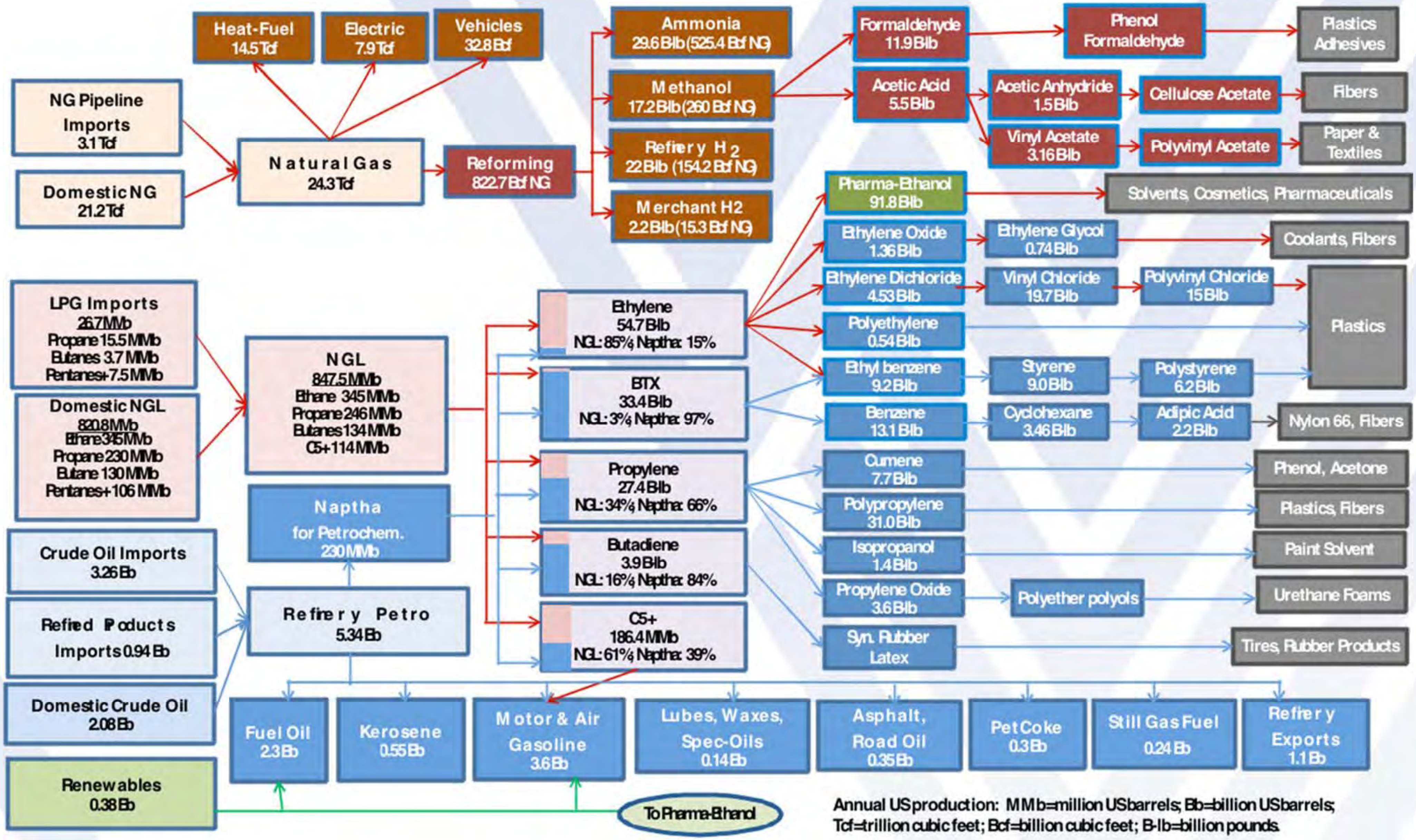
- According to American Chemistry Council (ACC) estimates, as of September 2015 companies from around the world have announced 246 projects and $153 billion in potential capital investments in U.S. chemical-processing facilities (ACC, 2016), up from 97 projects and $72 billion as of March 2013 (ACC, 2013).
- Largely as a result of the shale gas boom, U.S. jobs related to plastics manufacturing alone are expected to grow by 462,000, or more than 20 percent over the next decade (ACC, 2015a).



Source: ACC analysis, Dec. 2010 - March 2016

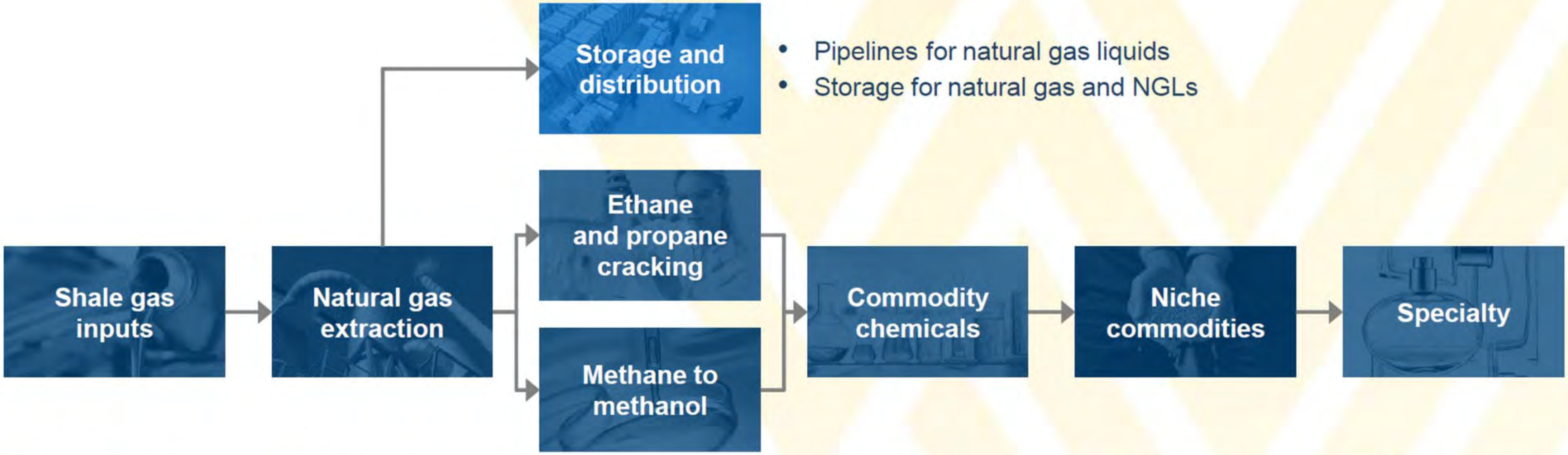
Source: American Chemistry Council, 2016

Hydrocarbon Products from Oil and Gas



Annual US production: MMb=million US barrels; Bb=billion US barrels; Tcf=trillion cubic feet; Bcf=billion cubic feet; B-lb=billion pounds.

Chemicals and Plastics Value Chain



Production or provision of things needed for fracking

- Equipment
- Sand (proppant)
- Water
- Chemicals
- Oilfield services

This includes:

- Drilling
- Transport
- Dehydration
- Fractionation

Two processes of gas to liquids

- Cracker projects
- Fischer-Tropsch synthesis

- Developing out-puts of crackers etc., one step to commodity plastics and chemicals
- Examples: ethylene to polyethylene, methanol to olefins

- Midstream industrial chemicals and plastics (e.g., dimethyl ether, propellants)

- Creating final products for B2B or B2C
- Includes industrial applications and consumer goods (performance plastics and perfumes)

Natural gas utilization: pathway toward a natural gas economy?

Significant R&D needs remain:

- **Process Synthesis:**
  - development and utilization of advanced algorithms to synthesize and model processes tailored for a specific characteristic

- **Reaction Engineering:**
  - leveraging scientific innovation, leveraged by technology pull and push, to develop processes (thermal, catalytic, photo, etc.) tailored for natural gas feeds.

- **Grand Challenges:**
  - exploit advances in fundamental computational and experimental sciences to rapidly identify optimum structure-function relationships
  - overcoming grand challenges associated with natural gas utilization (C1 activation, H-cleavage, coking, etc.).

American Institute of Chemical Engineers Natural Gas Utilization Workshop

CEI Center for Energy Initiatives

Natural Gas Utilization Workshop

Overcoming Hurdles of Technology Implementation

November 1-3, 2016

Waterfront Place Hotel, Morgantown, WV

This workshop will bring together leaders in downstream natural gas conversion across industry, academia and government to discuss various perspectives on hurdles to technology implementation.

Online registration is now closed, but on-site registration will be available.

Registration is $400 and includes a light reception on Nov. 1, lunch on Nov. 2, and coffee breaks in addition to workshop participation.

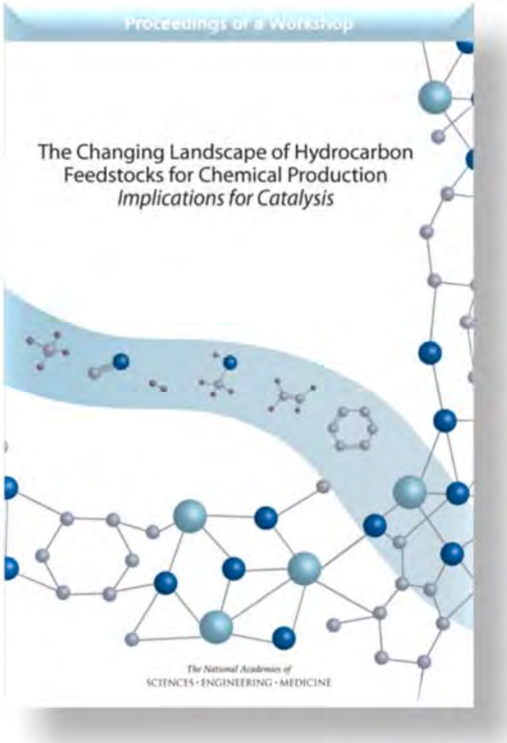
Objectives:

- Examine features of the downstream industry that have successfully adopted some new, beneficial technologies
- Understand how these features affect the development and commercialization of natural gas technologies
- Provide recommendations to federal agencies to accelerate the rate of technology adoption based on the diverse stakeholder interests along and across the natural gas value chain

Participating Organizations:

- Amec Foster Wheeler
- Anderson Energy
- Argonne National Laboratory
- Chemical Alliance Zone
- Covestro, LLC
- DOE
- The Dow Chemical Company
- ExxonMobil
- Gas Technology Institute
- Idaho National Laboratory
- MATRIC
- NETL
- The Ohio State University
- Pennsylvania State University
- Reaction 35, LLC
- Siluria Technologies
- Texas A&M University
- University of Pittsburgh
- West Virginia University

Utilization of Natural Gas



Disproportionation

Aromatization

Synthesis gas generation

Direct selective oxidation

Metathesis

Oxidative coupling

CH_4

C_3H_8

C_2H_6

Ethane steam cracking

Oxidative dehydrogenation

Selective oxidation ethanol/acetaldehyde/acetic acid

Selective oxidation ethylene oxide

Dehydrogenation

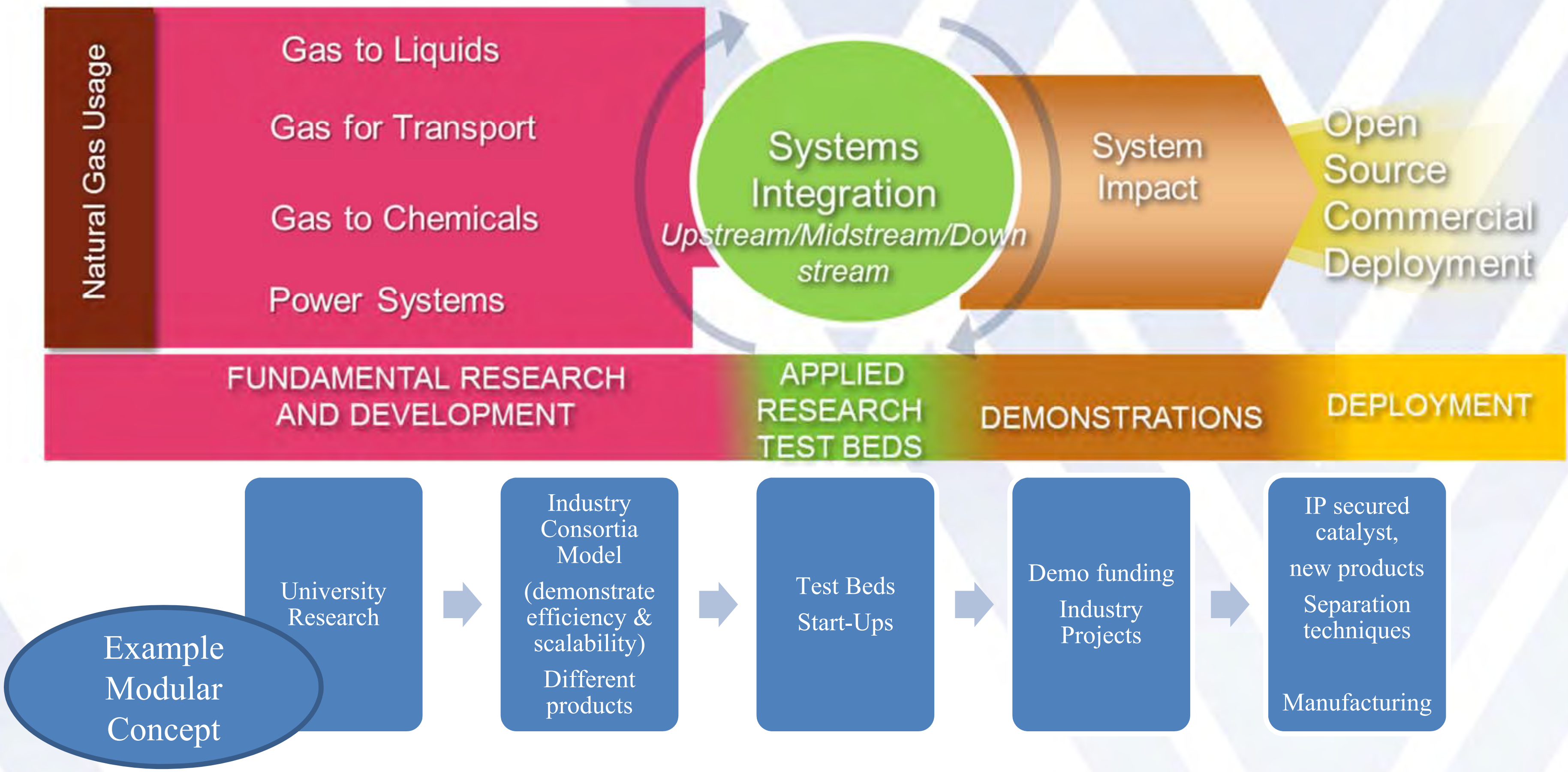
Oxidative dehydrogenation

Selective oxidation to acrolein/acrylic acid/acrylonitrile

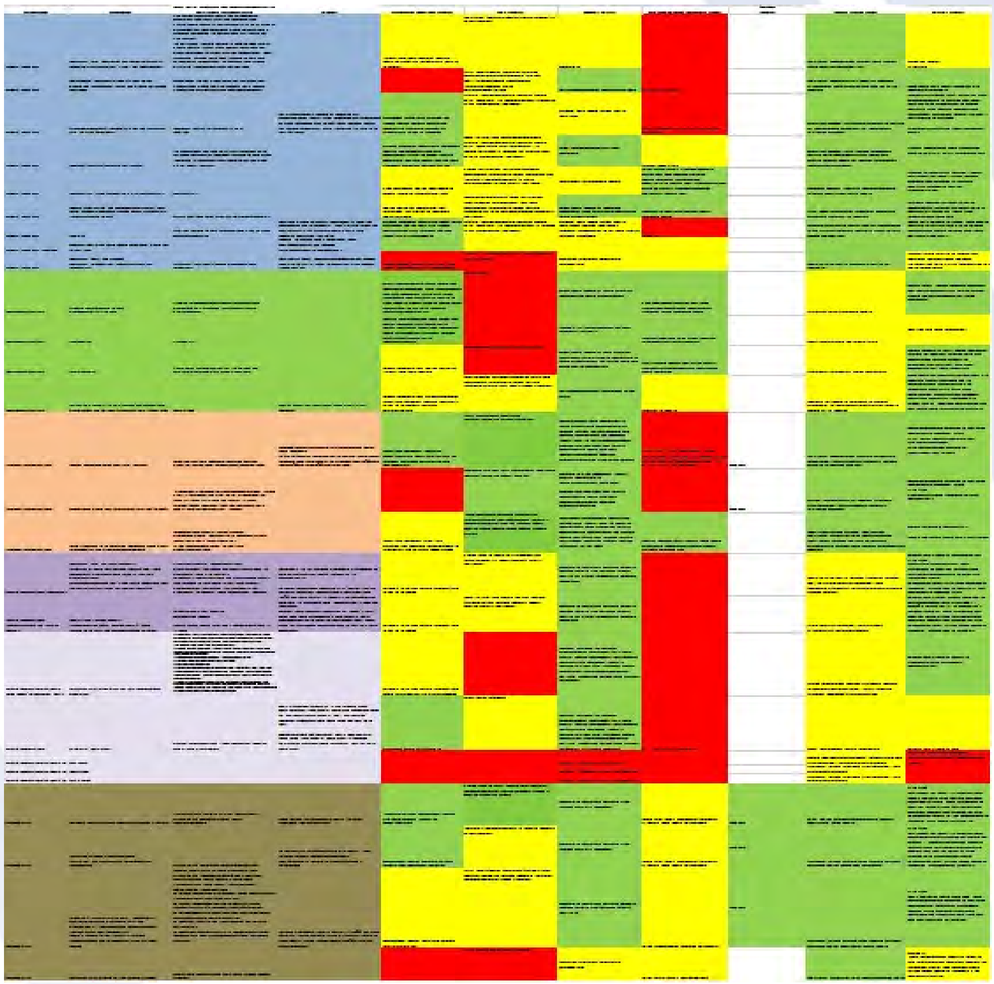
Lercher, J.. 2016. "Overview of the Shale Gas Boom and its Impact on the Chemical Industry." Presented at the Board on Chemical Sciences and Technology Workshop on The Changing Landscape of Hydrocarbon Feedstocks for Chemical Production: Implications for Catalysis, Washington, DC, March 7–9, 2016.

Examples: Connecting the Dots

How innovation builds to economic development



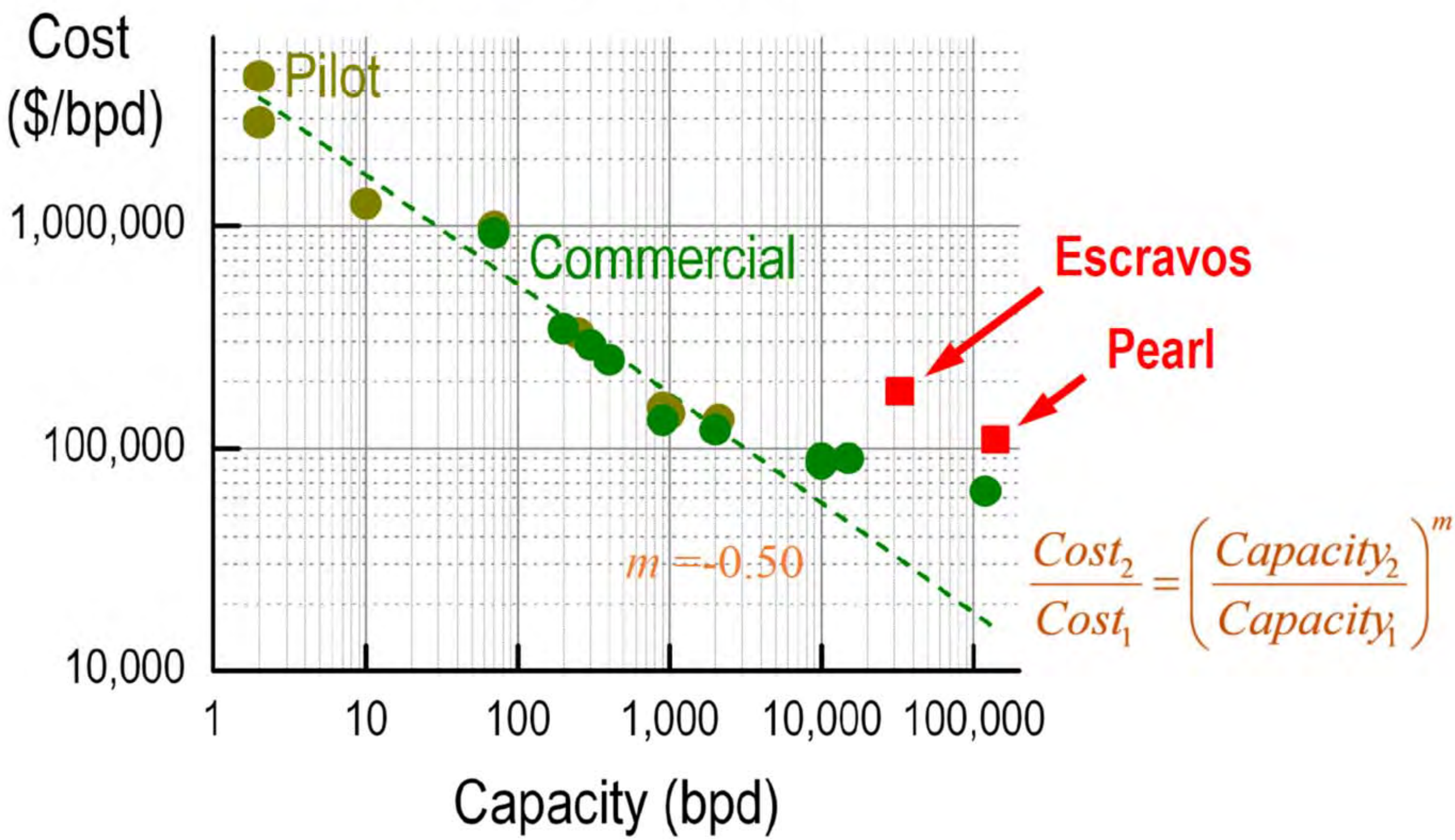
Regional strengths were assessed against 25+ ideas industry identified to grow gas usage



- We evaluated 25 ideas to grow gas usage, identified at 2 industry roundtables, to highlight regional strengths.
- The heat map identified areas where we have national credibility

Economies of Scale: Is bigger always better?

GTL Cost vs. Capacity[9]



PJA Tijm. *Gas to liquids, Fischer-Tropsch, advanced energy technology, future's pathway*. Feb 2010.

Conversion of Methane

- **Methane to Syngas**

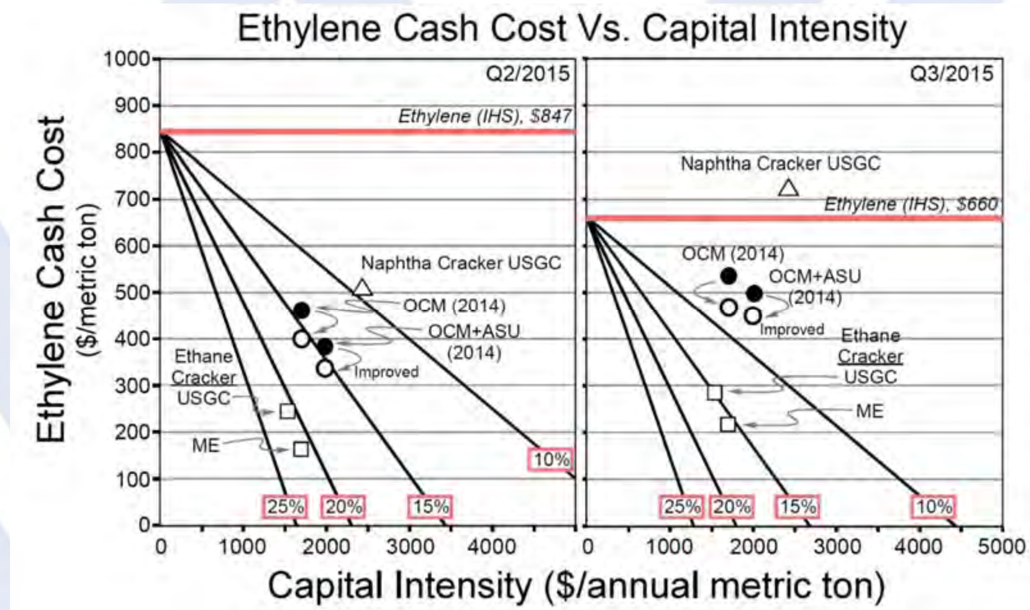
  Opportunities

  – Develop oxygen ion- and proton-conducting ceramic membranes as dual-function materials that would replace the current energy intensive methods used to separate oxygen from air and also serve as a catalyst support matrix.

  – Determine if additive manufacturing using three-dimensional printing could enable co-printing copper or tin catalysts with reactor internals to improve heat transfer, a crucial parameter for methane-to-syngas processes.

  – Develop advanced heat-exchange systems and catalyst supports with novel structures

Conversion of Methane



- **Methane to Ethylene**

  Impediments to commercial viability:

  – The lack of substantial capital investment to build an industrial-scale facility for oxidative coupling compared with building an ethane cracker

  – Selectivity for producing ethylene

    - poor selectivity increases the expense of separating ethylene from the reaction byproducts.

  – Development of cost-effective and robust membrane separation technologies could significantly improve the economic competitiveness of methane oxidative coupling to produce ethylene

    - though the relative low cost of ethane compared to methane today makes the economics of methane-to-ethylene conversion challenging even with technological improvements

Maughon, B. 2016. "Methane to Ethylene: Drivers, History, Challenges, and Current Developments." Presented at the Board on Chemical Sciences and Technology Workshop on The Changing Landscape of Hydrocarbon Feedstocks for Chemical Production: Implications for Catalysis, Washington, DC, March 7–9, 2016.

Conversion of Methane

- **Methane to Aromatics**

  Barriers:
  - deactivation of the catalyst by coking;
  - low methane conversion rates that result from the buildup of hydrogen;
  - capital costs associated with this process relative to that for aromatics production from petroleum; and
  - the lack of cost-effective methods to remove H_2 from the reactor and to separate benzene from naphthalene

  Research Opportunities:
  - rigorous high-temperature characterization during reaction;
  - reproducing and understanding high-temperature results;
  - high-temperature material stability and catalyst support;
  - fast reactions with short-residence/contact/surface interaction time;
  - catalyst/process modification to avoid coke formation;
  - exploring the possibilities for hybrid-solid-molten salt catalyst;
  - using predictive methods to create catalysts by design;
  - developing non-ZSM-5 catalyst systems;
  - identifying and studying non-oxidative chemistries; and
  - conceptualizing new reactor designs and technologies.

Conversion of Methane

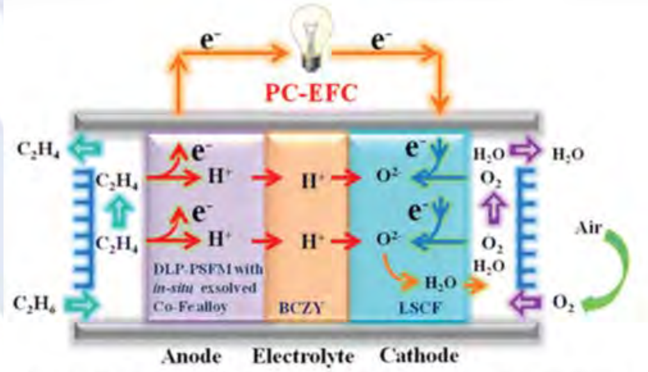
- **Methane to Methanol**

  Challenges:
  - managing heat and mass transfer;
  - catalytic selectivity;
  - product separation and purification;
  - catalyst cost and supply security; and
  - catalyst lifetime and regeneration.

  Advances useful in addressing the challenges:
  - operando and ex-situ spectroscopy to probe catalyst structure and dynamics;
  - new chemical and analytical techniques to probe mechanism;
  - high-throughput experimentation for optimization and discovery;
  - materials science of catalyst supports and plant construction materials;
  - ligand supply and design;
  - advances in synthesizing catalysts; and
  - high-powered computational approaches for both understanding and prediction.

Emerging Opportunities for Novel Approaches

- **Electrocatalysis**
  - Fuel cells
    - ethane-to-ethylene (Liu et al., 2016)
    - methane to ethane and ethylene (Kiatkittipong et al., 2004; Quddus et al., 2010)
  - Electrocatalytic conversion of methane to methanol (Fan, 2015; Lee and Hibino, 2011; Spinner and Mustain, 2013)
- **Biocatalysis**
  - Through metabolic engineering
  - Poor yield reported thus far



Anode: $(Pr_{0.4}Sr_{0.6})_3(Fe_{0.85}Mo_{0.15})_2O_7$/Co-Fe alloy nanoparticles

$C_2H_6 \rightarrow C_2H_4 + 2H^+ + 2e^-$

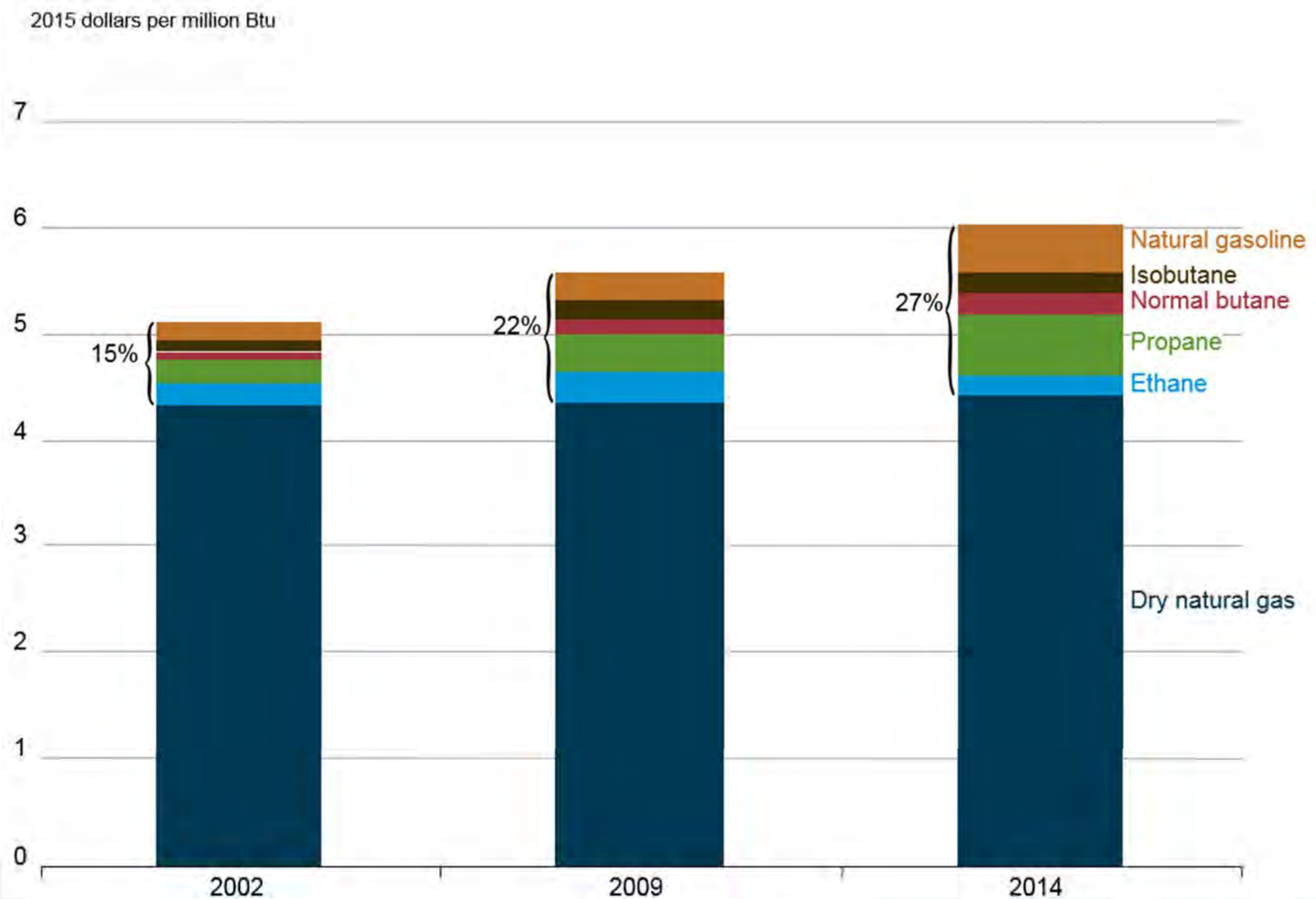
H^+ Electrolyte: $BaCe_{0.7}Zr_{0.1}Y_{0.2}O_{3-\delta}$

Cathode: $(La_{0.6}Sr_{0.4})_{0.95}Co_{0.20}Fe_{0.80}O_{3-\delta}$

$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$

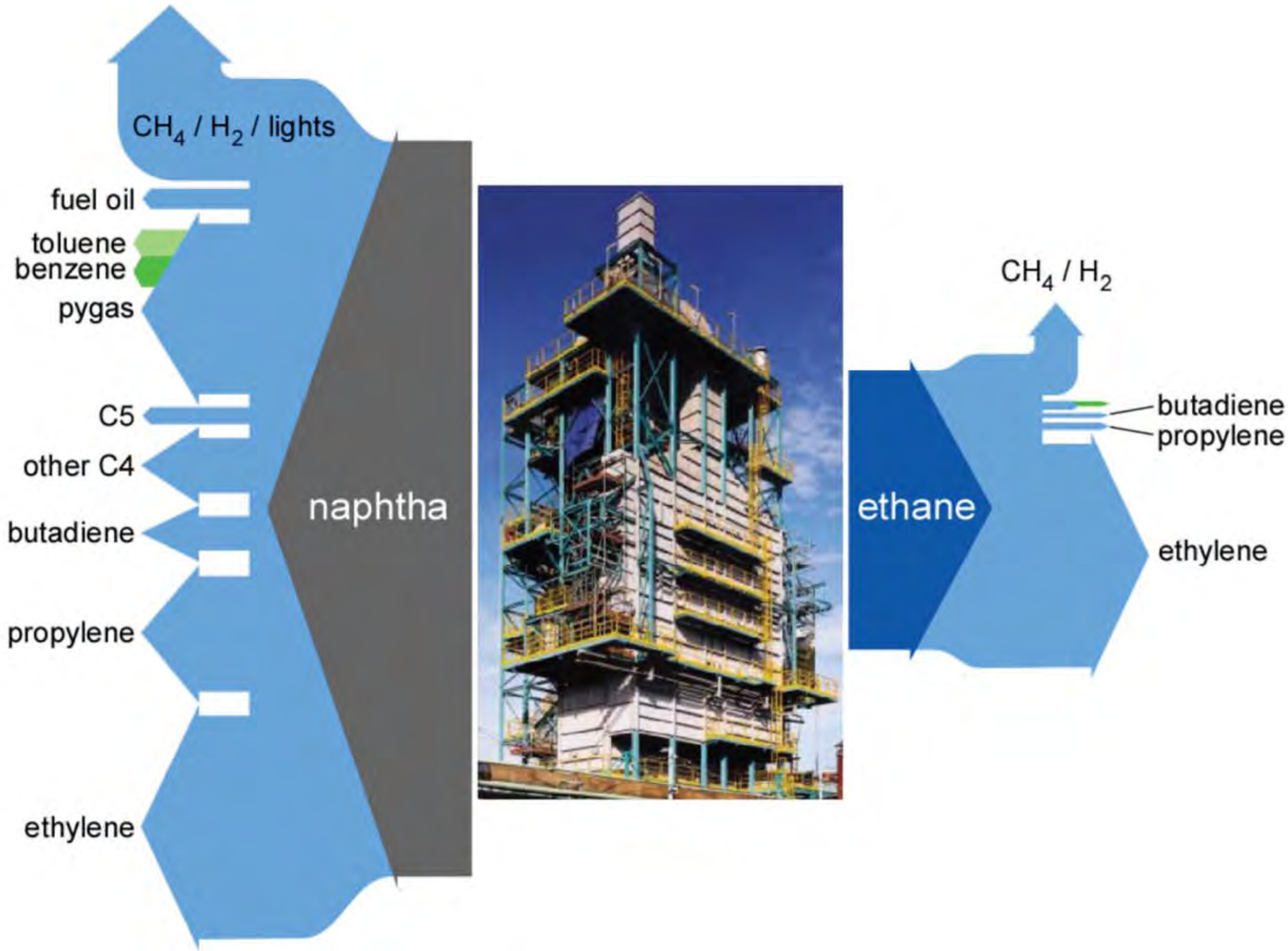
FIGURE 4-12 Ethane to ethylene fuel cell.
SOURCE: Liu et al., 2016.

Values of U.S. natural gas liquids and dry gas



Source: EIA

Ethane vs. Naptha Cracking

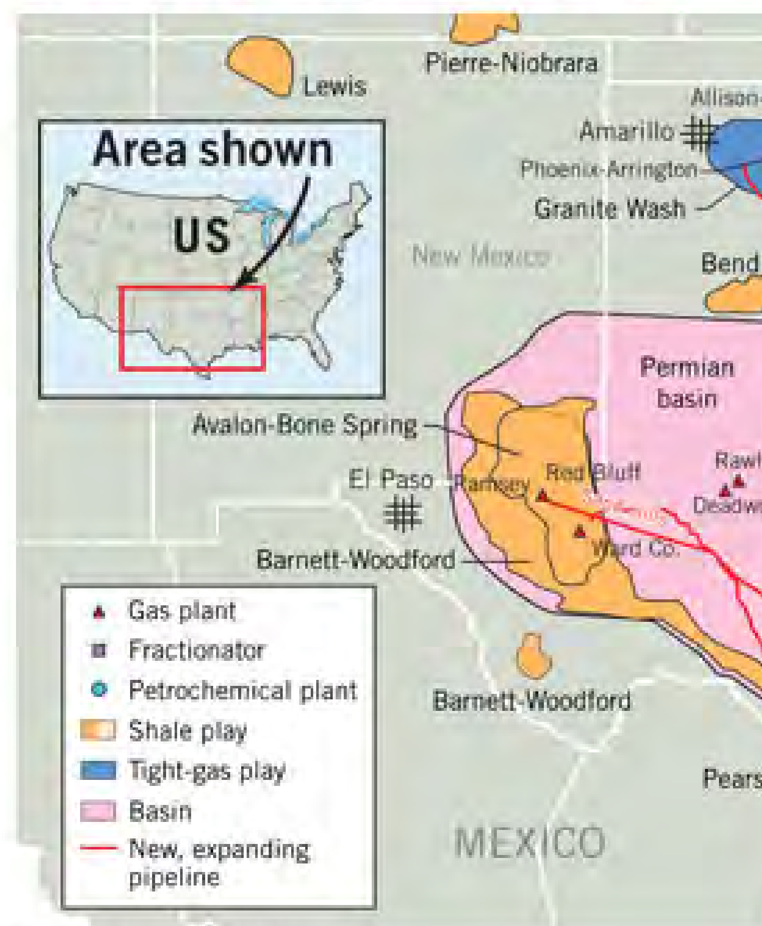


Jones, M. 2016. “Overview of the Shale Gas Boom and its Impact on the Chemical Industry.” Presented at the Board on Chemical Sciences and Technology Workshop on The Changing Landscape of Hydrocarbon Feedstocks for Chemical Production: Implications for Catalysis, Washington, DC, March 7–9, 2016.

New Fractionation Capacity in the U.S.

NEW GAS PLANTS, FRACTIONATORS: OKLA.-TEX.

FIG. 1



Map data generated by PennWell MAPSearch, Houston.

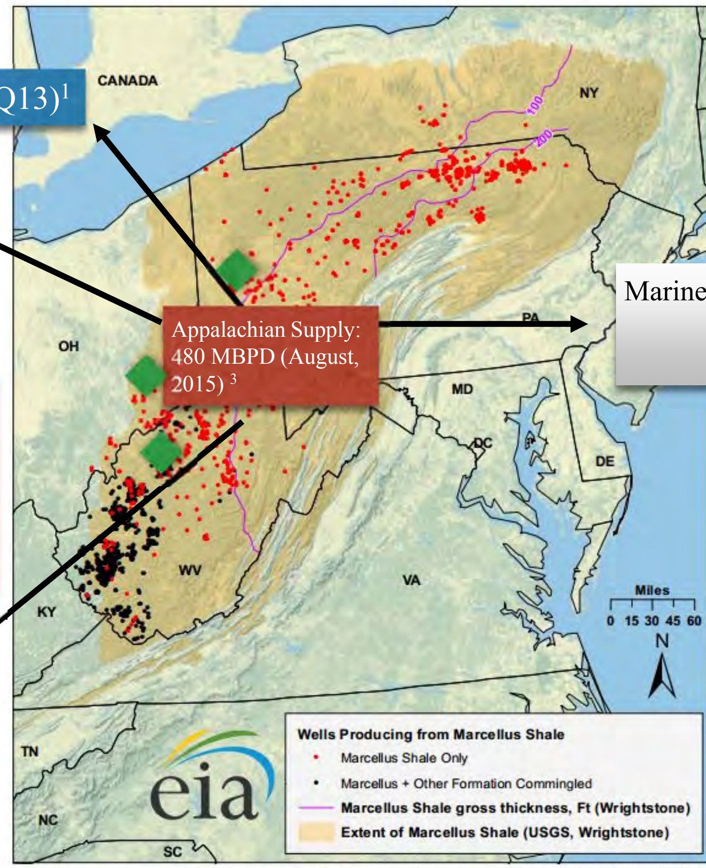
NEW GAS PLANTS, FRACTIONATORS: APPALACHIA

FIG. 4

Map data generated by PennWell MAPSearch, Houston.

Estimated Ethane Supply and Announced Demand

Marcellus Shale Gas Play, Appalachian Basin



Source: US Energy Information Administration based on data from WVGES, PA DCNR, OH DGS, NY DEC, VA DMME, USGS, Wrightstone (2009). Only wells completed after 1-1-2003 are shown. Updated June 1, 2011

Mariner West (MW): 50 MBPD (4Q13)[1]

KM Utopia (MW): 18 MBPD (1Q18)[1]

Appalachian Supply: 480 MBPD (August, 2015) [3]

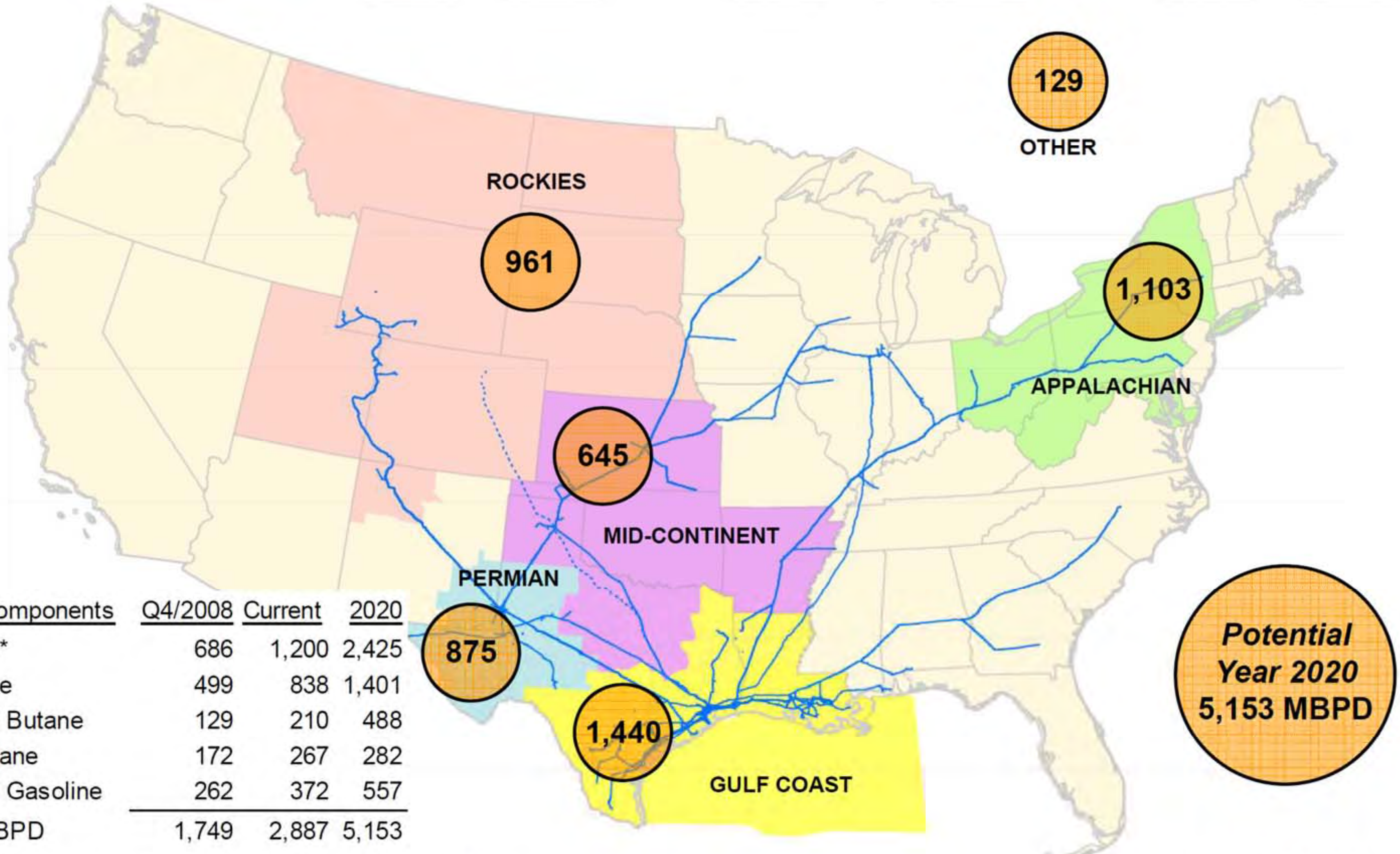
Mariner East (ME): 23 MBPD (4Q15)
91 MBPD (1Q17)
Total: 115 MBPD [2]

Steam Crackers [5]
Shell: 105 MBPD (2019)
PTTGC: 65 MBPD (2020)
Braskem: 65 MBPD (2021)
Total: 235 MBPD

ATEX (AX): 65 MBPD (1Q14)
60 MBPD (Future)
Total: 125 MBPD [4]

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)

U.S. NGL Supply Potential Assuming Sufficient Markets (MBPD)

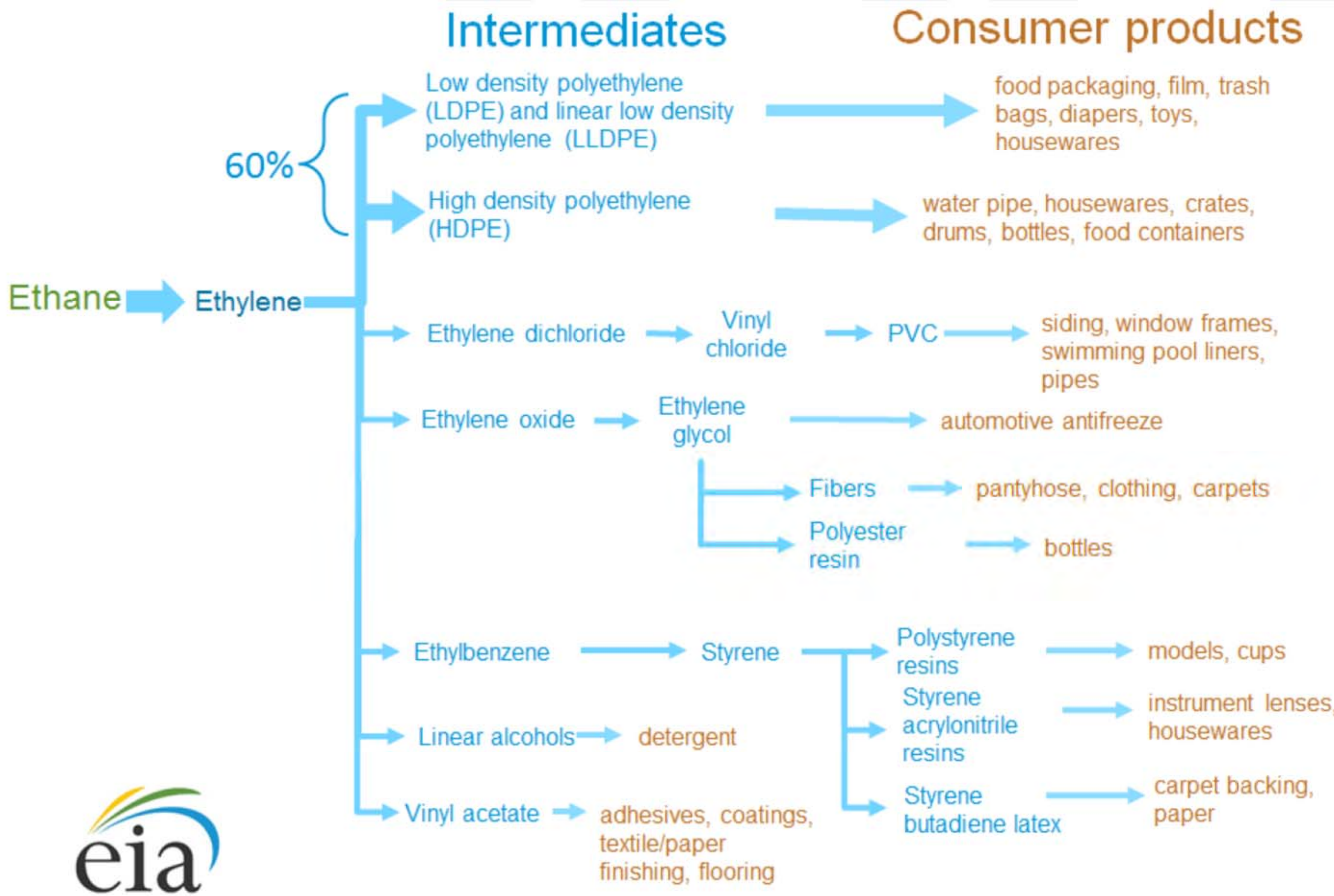


NGL Components	Q4/2008	Current	2020
Ethane*	686	1,200	2,425
Propane	499	838	1,401
Normal Butane	129	210	488
Iso Butane	172	267	282
Natural Gasoline	262	372	557
MBPD	1,749	2,887	5,153

** Current is increased by 200–250 MBPD for estimated ethane rejection*

Source: EPD Fundamentals

Ethane Product Streams



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

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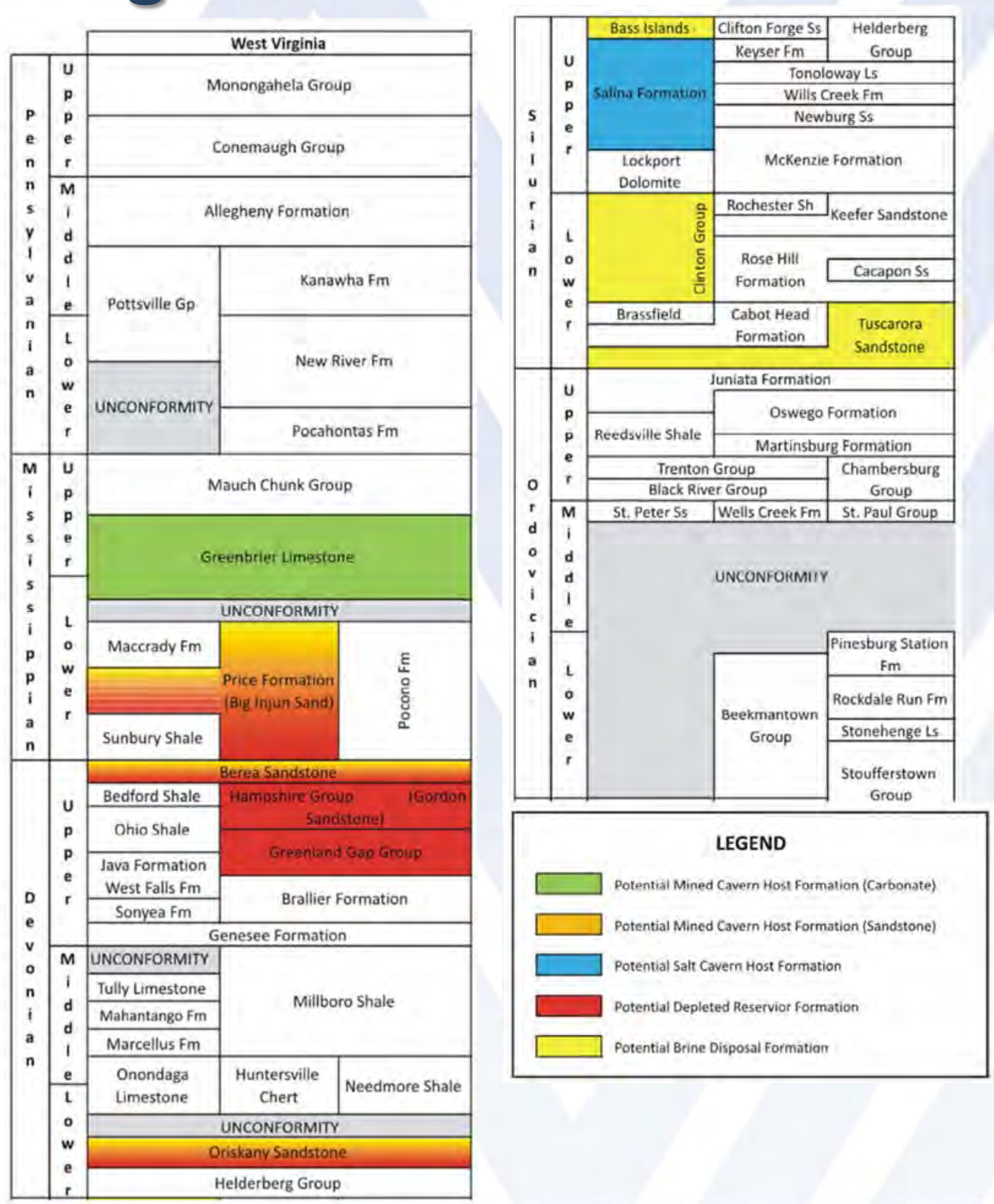
WVONGA West Virginia Oil and Natural Gas Association
BLUEracer MIDSTREAM
SWN Southwestern Energy
Dominion

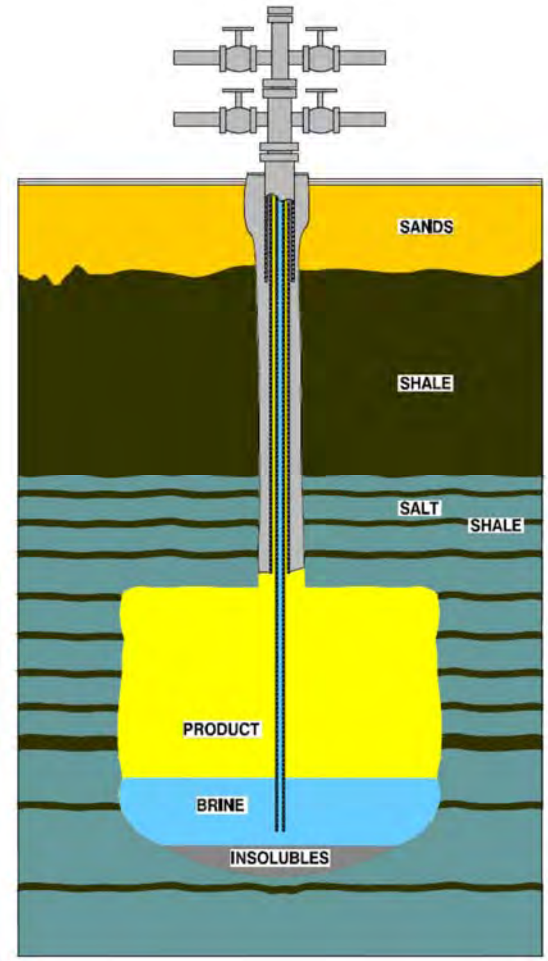
Stratigraphic Units Investigated

- Greenbrier Limestone
- Salina salt beds
- Mississippian sandstones (Keener to Berea)
- Upper Devonian sandstones (Bradford, Venango, Elk)
- Oriskany Sandstone
- Clinton – Medina through Tuscarora Sandstone
- Upper Sandy Member of the Gatesburg Formation
- Rose Run Sandstone



Types of Potential Ethane 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



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

Appalachian Storage Hub Work Plan

- Data collection (well logs & cores); database creation
- Stratigraphic correlation of key lithologic units
- Map the thickness, extent & structure of key lithologic units
- Conduct studies of reservoir character and storage potential of key lithologic units
- Develop ranking criteria for potential storage zones
- Make final recommendations for the ethane storage hub location

Generalized distribution and thickness of Salina salt beds (modified in part from Fergusson and Prather, 1968; Griggs, 1958; Sanford, 1965; and Rickard, 1969

Conclusion

- There is an abundance of natural gas (containing NGLs) in the shales of the U.S.
  - NGL production from the Appalachian Basin has increased tenfold over this time, from a baseline of under 30,000 bbl/day to nearly 400,000 bbl/day in 2016.
- The Appalachian Basin provides 1) access to markets, and 2) a competitive pricing advantage due to the abundance of valuable (yet currently underpriced) hydrocarbons
  - Transportation costs for transporting ethane via pipe from the Appalachian Basin to Mont Belvieu is approximately $0.16, while the cost for rail transportation of propane is $0.30. The current Mont Belvieu prices for ethane and propane are $0.21 and $0.43
- Ethane storage is key to the development of a robust NGLs trading post, i.e. a spot market essential to further development of the chemical manufacturing industry in this region
- A storage facility will be tied into the overall play via massive piping infrastructure
- The U.S. and Mid-Atlantic Region would benefit from infrastructure development to satisfy the feedstock and offtake requirements for world scale and/or distributed manufacturing elements

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