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Shale Plays:

How Technology, Governments, Regulators, Academia, and the Public Have Changed the World's Energy Supply and Demand Equation

Joseph H. Frantz, Jr.

VP Engineering Technology

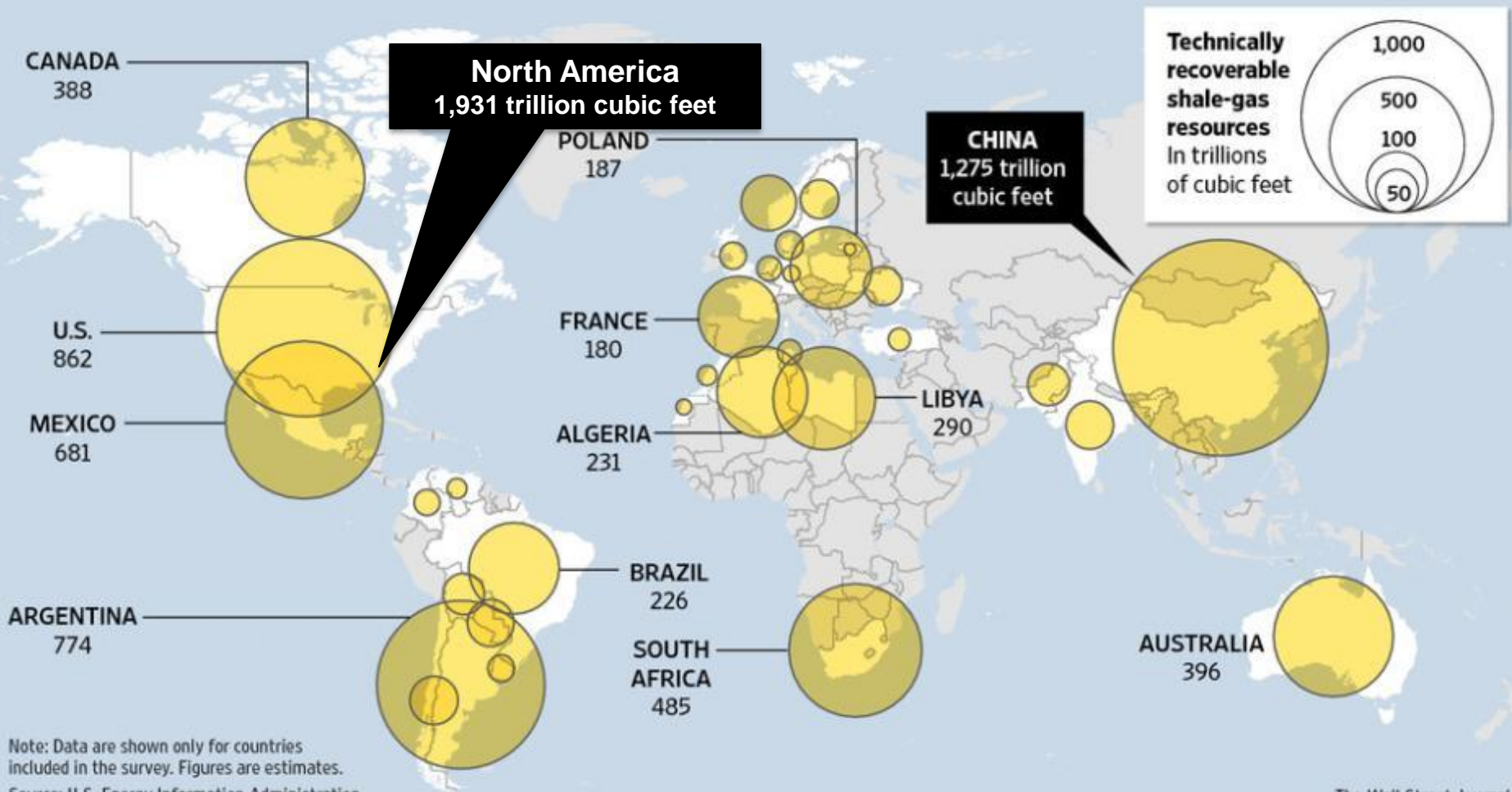


RANGE RESOURCES®

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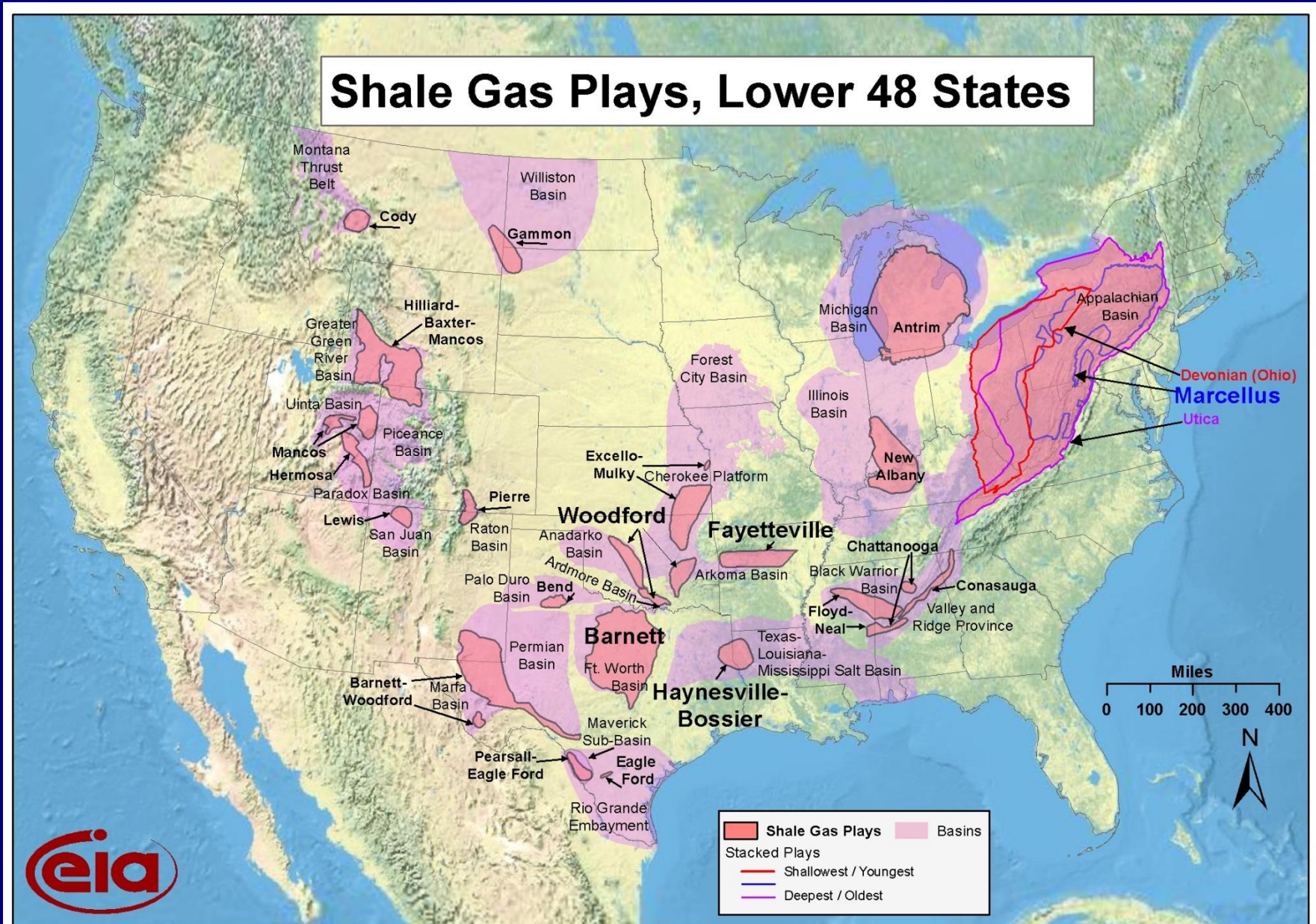
Shale Gas – Global Opportunity

An Elusive Prize | Many nations are believed to have large shale deposits



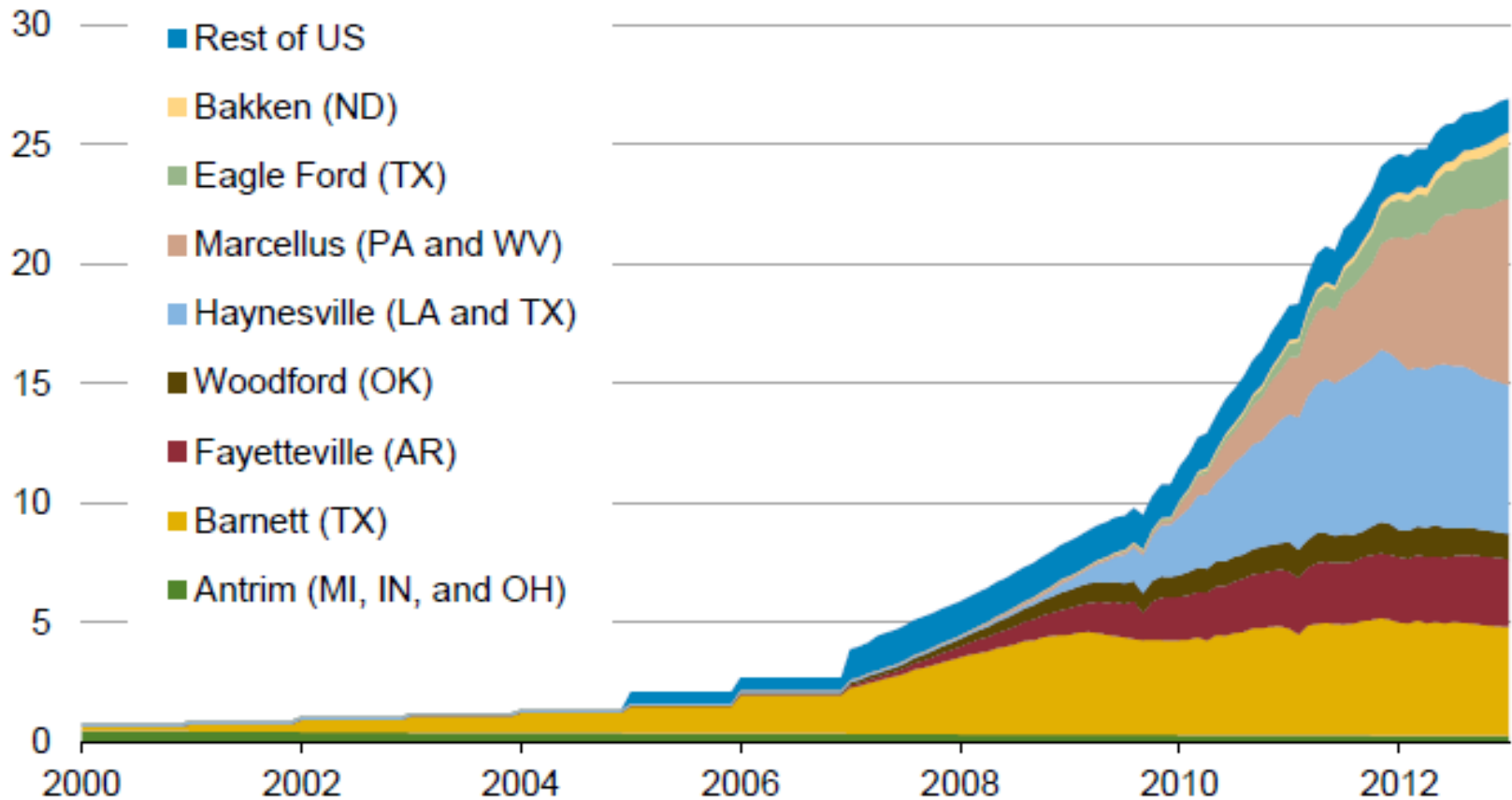
The Wall Street Journal

Shale Gas Revolution Across the U.S.



US Shale Gas Production Increases in Recent Years

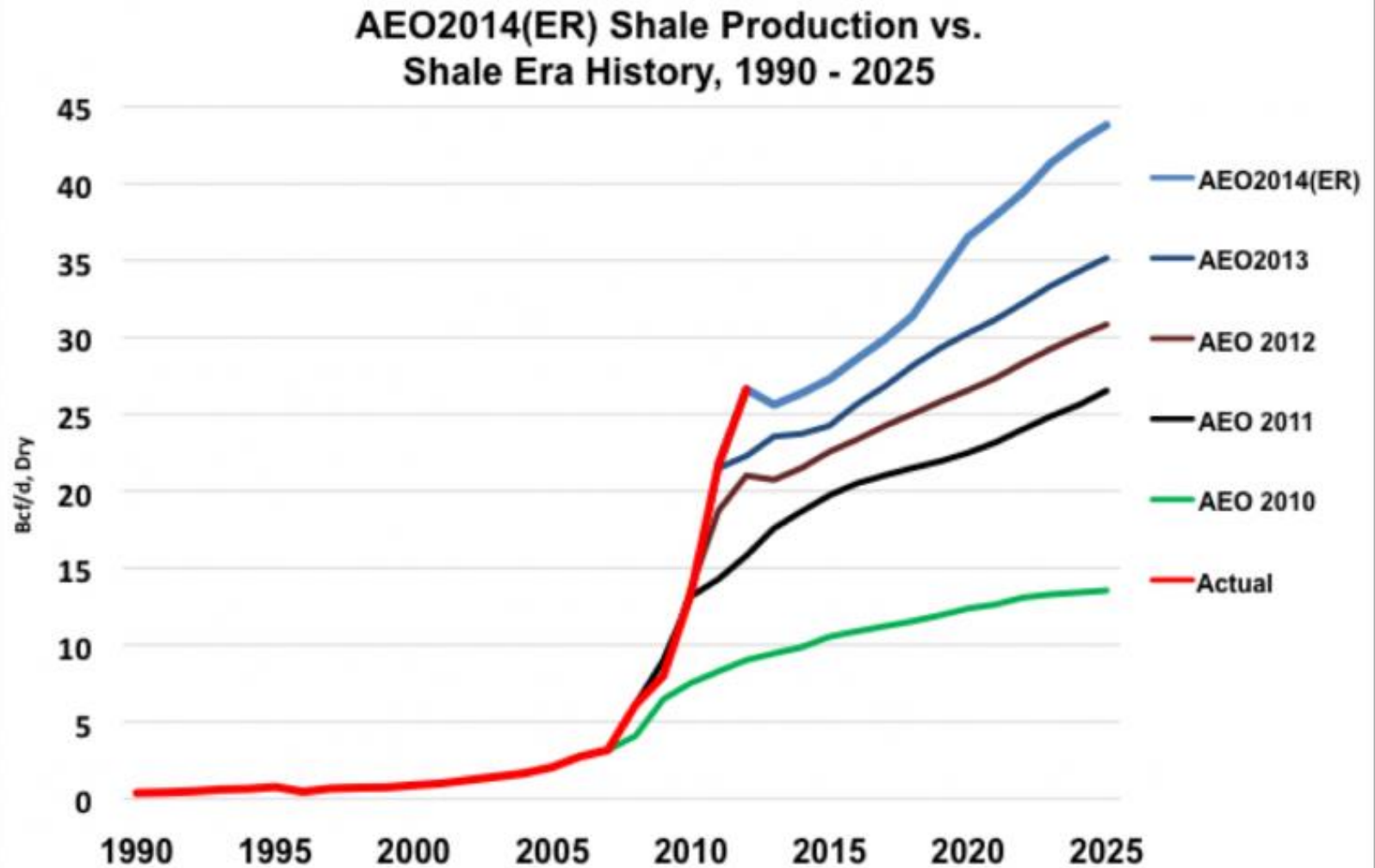
shale gas production (dry)
billion cubic feet per day



Sources: LCI Energy Insight gross withdrawal estimates as of January 2013 and converted to dry production estimates with EIA-calculated average gross-to-dry shrinkage factors by state and/or shale play.

Previous US Shale Gas Forecasts Were Low

Figure 6

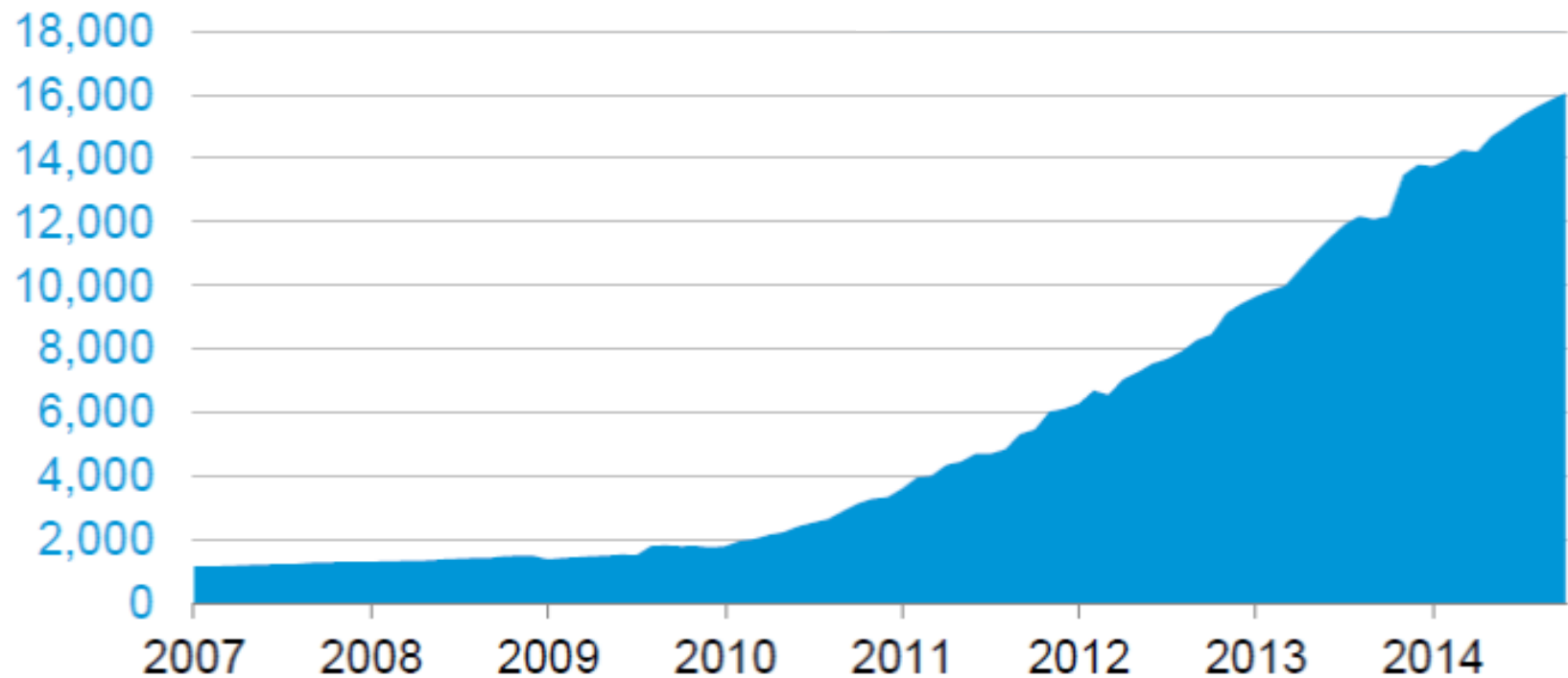


Source: EIA, Annual Energy Outlook 2014, Early Release, Historic Data

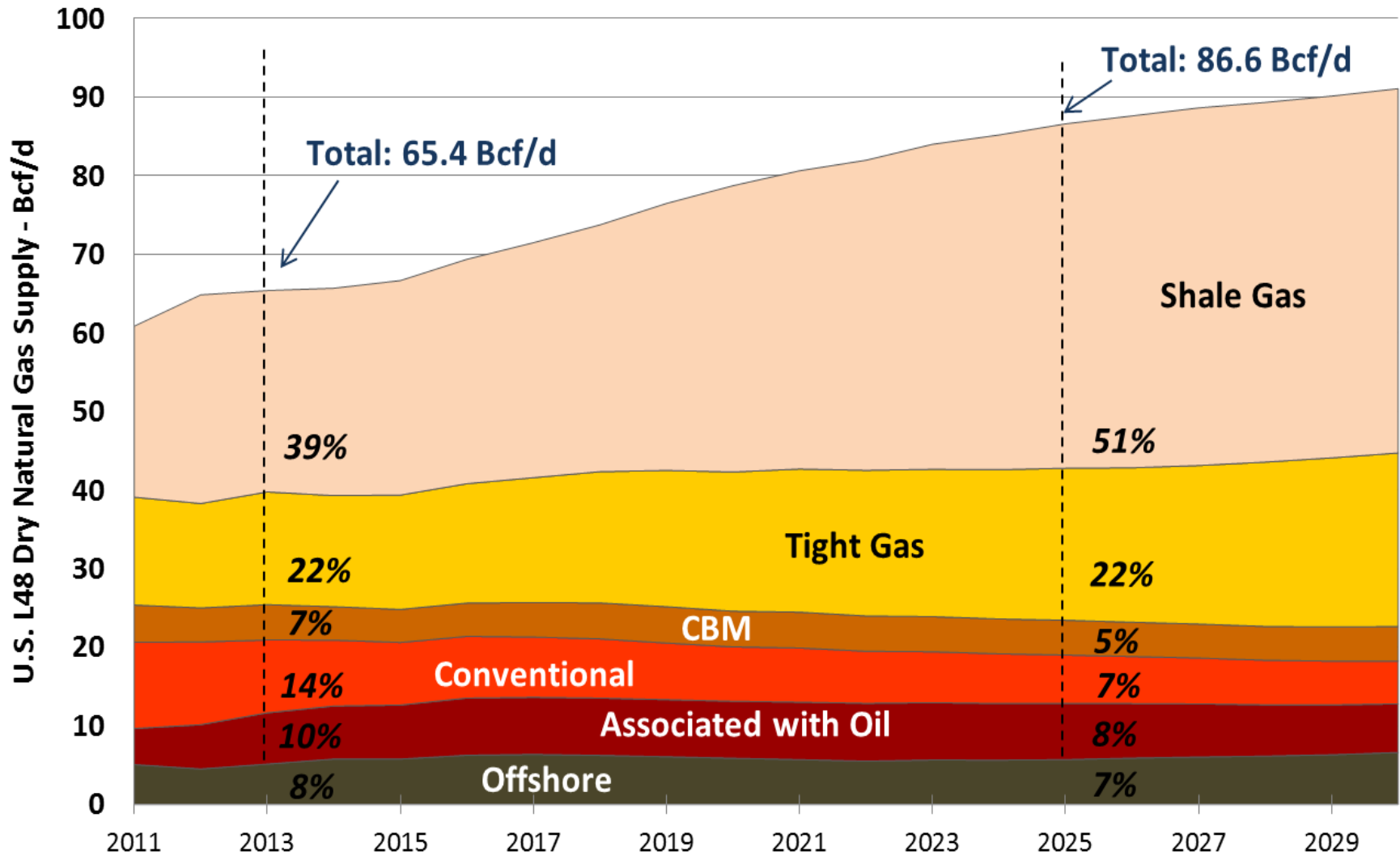
Marcellus Gas Production Continually Increasing

Marcellus Region Natural gas production

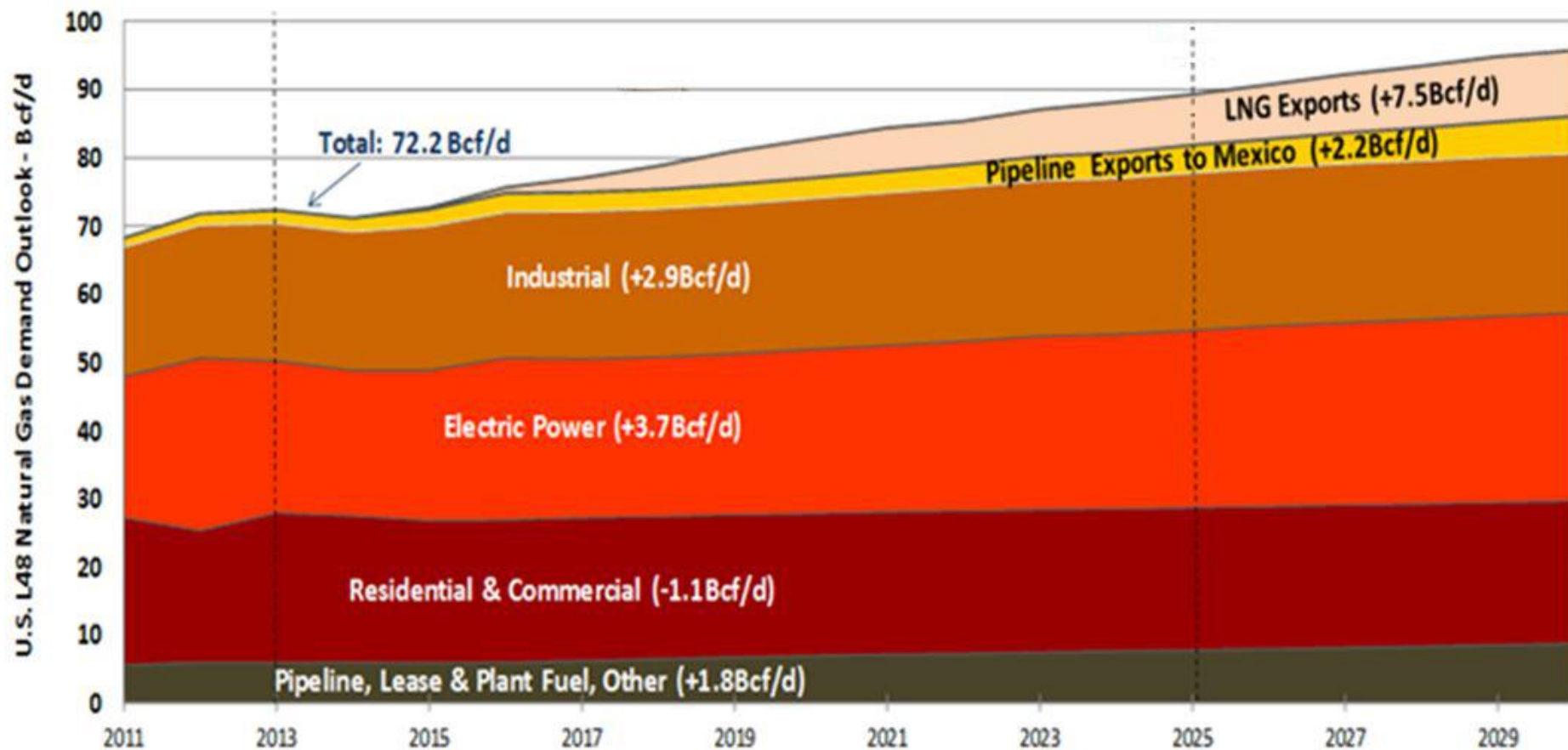
million cubic feet/day



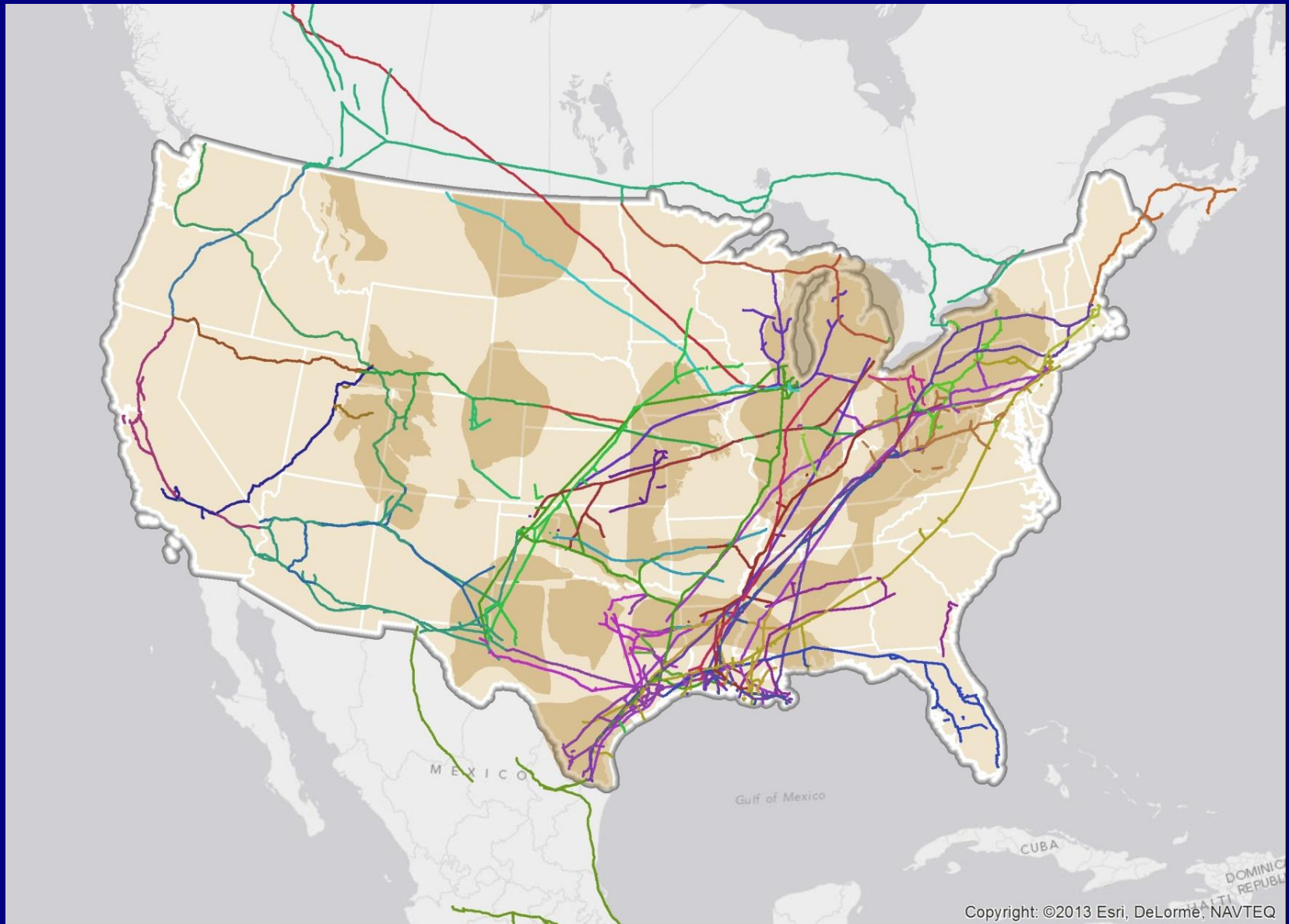
Shale Gas Projected to Lead US Growth



US Gas Demand Expected to Increase



Natural Gas Pipeline Infrastructure Is Growing



Proposed Infrastructure Projects in Marcellus Play

Incremental capacity: +16.3 Bcfd

North & Northeast
 Constitution Pipeline
 Williams NE Connector
 Spectra AIM Project
 +1.7 Bcfd

West & Northwest
 TETCO/DTE/Enbridge NEXUS Pipeline
 TETCO Uniontown to Gas City
 Rockies Express
 Energy Transfer Rover
 +5.4 Bcfd

Metropolitan NY Area
 Williams Rockaway Lateral
 +0.6 Bcfd

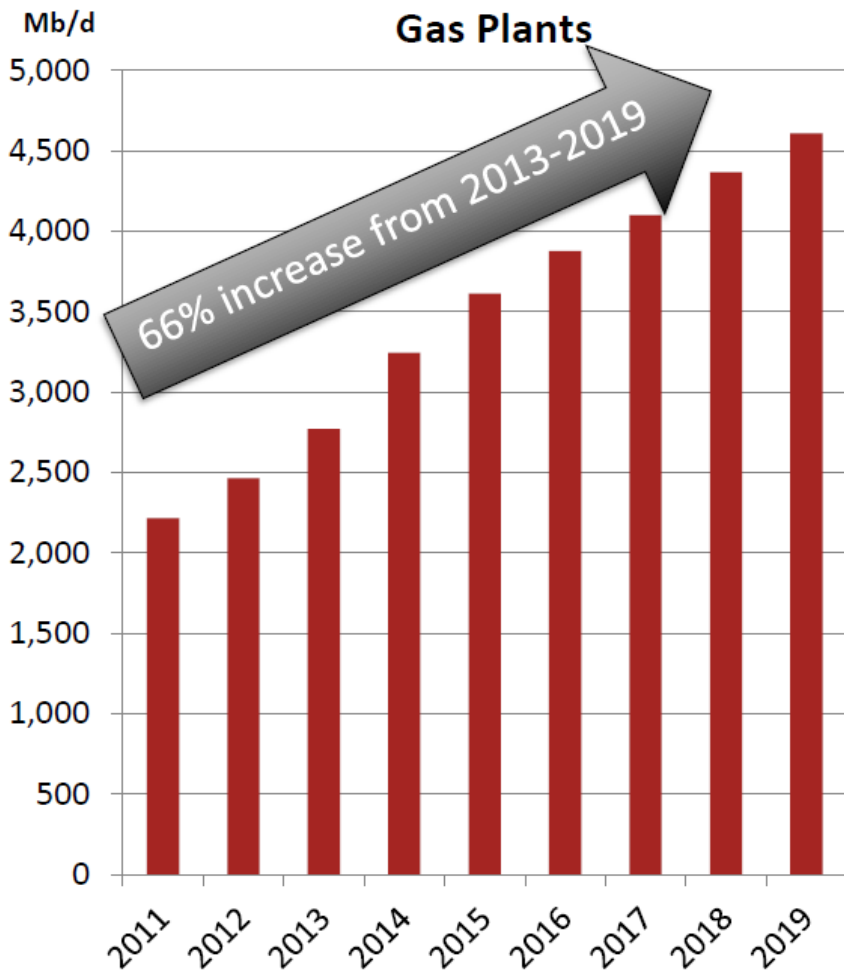
South & Southwest
 NiSource (TCO) West Side Expansion
 TETCO OPEN Project
 TETCO TEAM 2014
 TETCO TEAM South
 TETCO Gulf Markets
 NiSource (TCO) Leach/Rayne Express
 TCO Gulf
 TGP Broadrun
 +5.5 Bcfd

Mid-Atlantic & Southeast
 NiSource (TCO) East Side Expansion
 Williams Leidy SE Expansion
 Williams Atlantic Sunrise
 TETCO Team 2014
 +3.1 Bcfd

*Data as of July 2014
 *Capacities and timing may vary
 *May not include all current projects

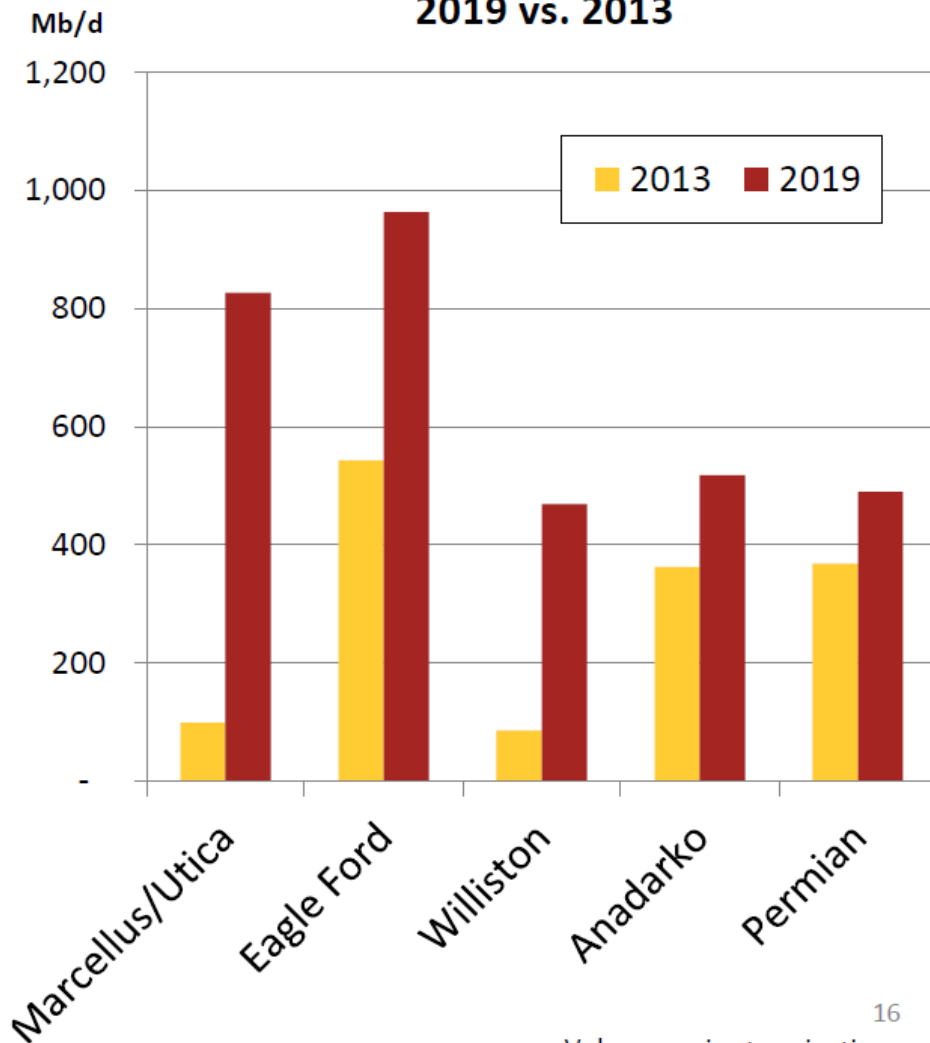
US NGL Supply Outlook

US NGL Production from Gas Plants



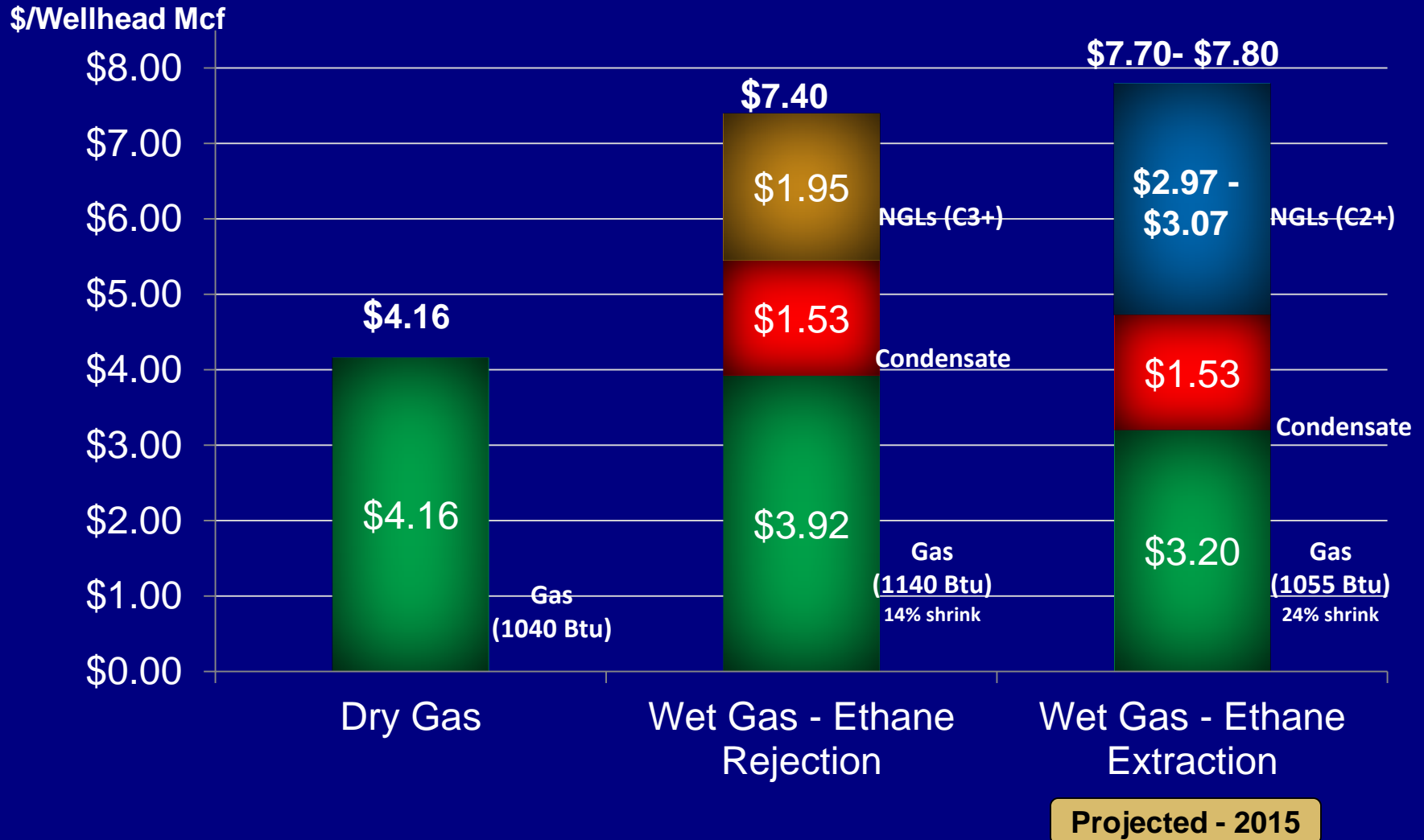
Source: Bentek's Market Call: North American NGLs

US NGL Production: 2019 vs. 2013



16
Volumes prior to rejection

Marcellus Wet Gas Provides Significant Price Uplift



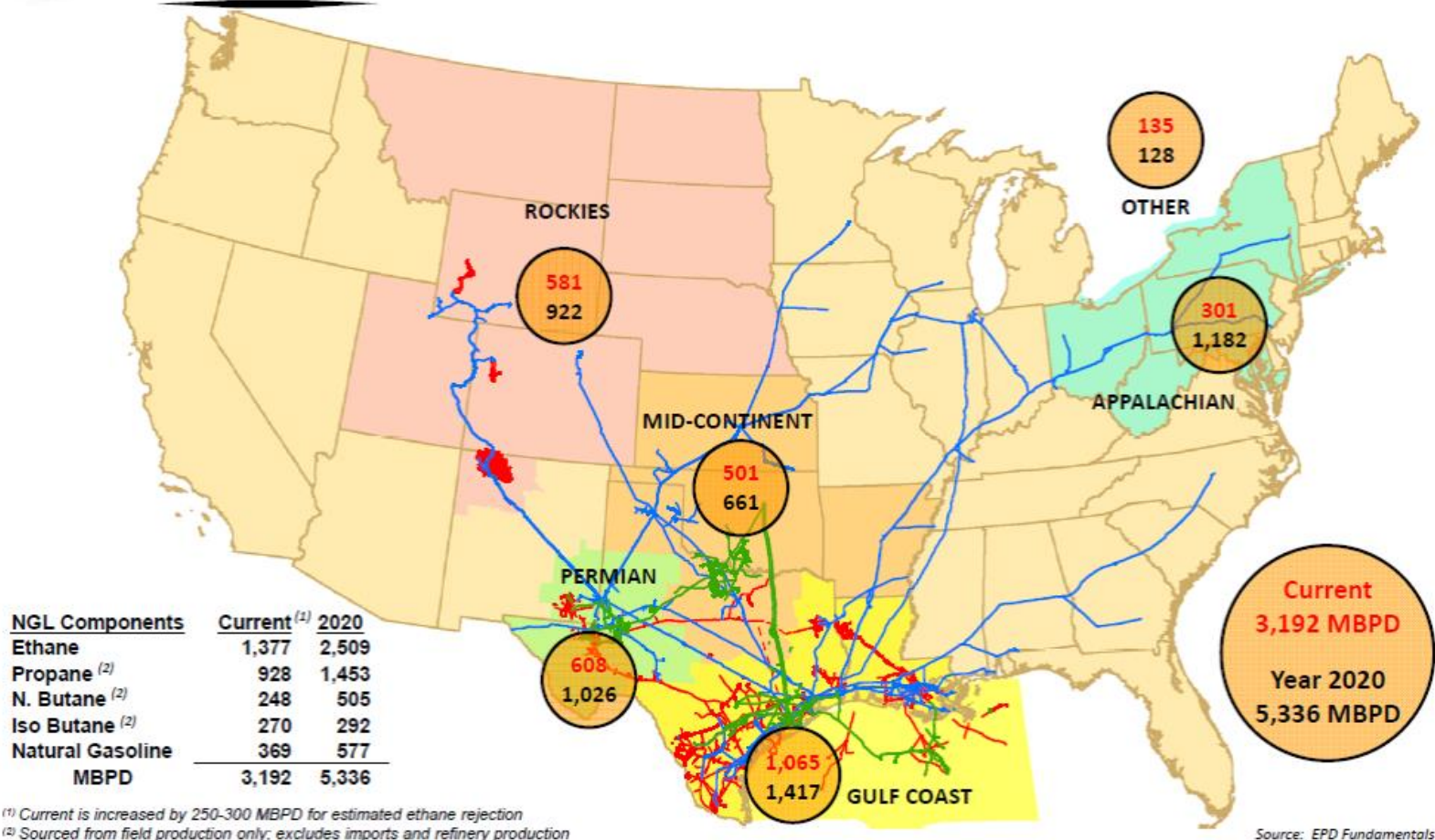
Range Resources

Assumptions: \$4.00 NG, \$90.00 WTI, 40% WTI (C3+), 2.27 GPM (ethane rejection), 5.60 GPM (ethane extraction), all processing, shrink, fuel & ethane transport included. Based on SWPA wet gas quality (1,275 processing plant inlet btu). Wet Gas (Ethane Extraction) based on full utilization of current ethane/propane agreements. NOTE: Wet Gas (Ethane Rejection) equals 1.3 mcf post-processing and Wet Gas (Ethane Extraction) equals 1.68 mcf.

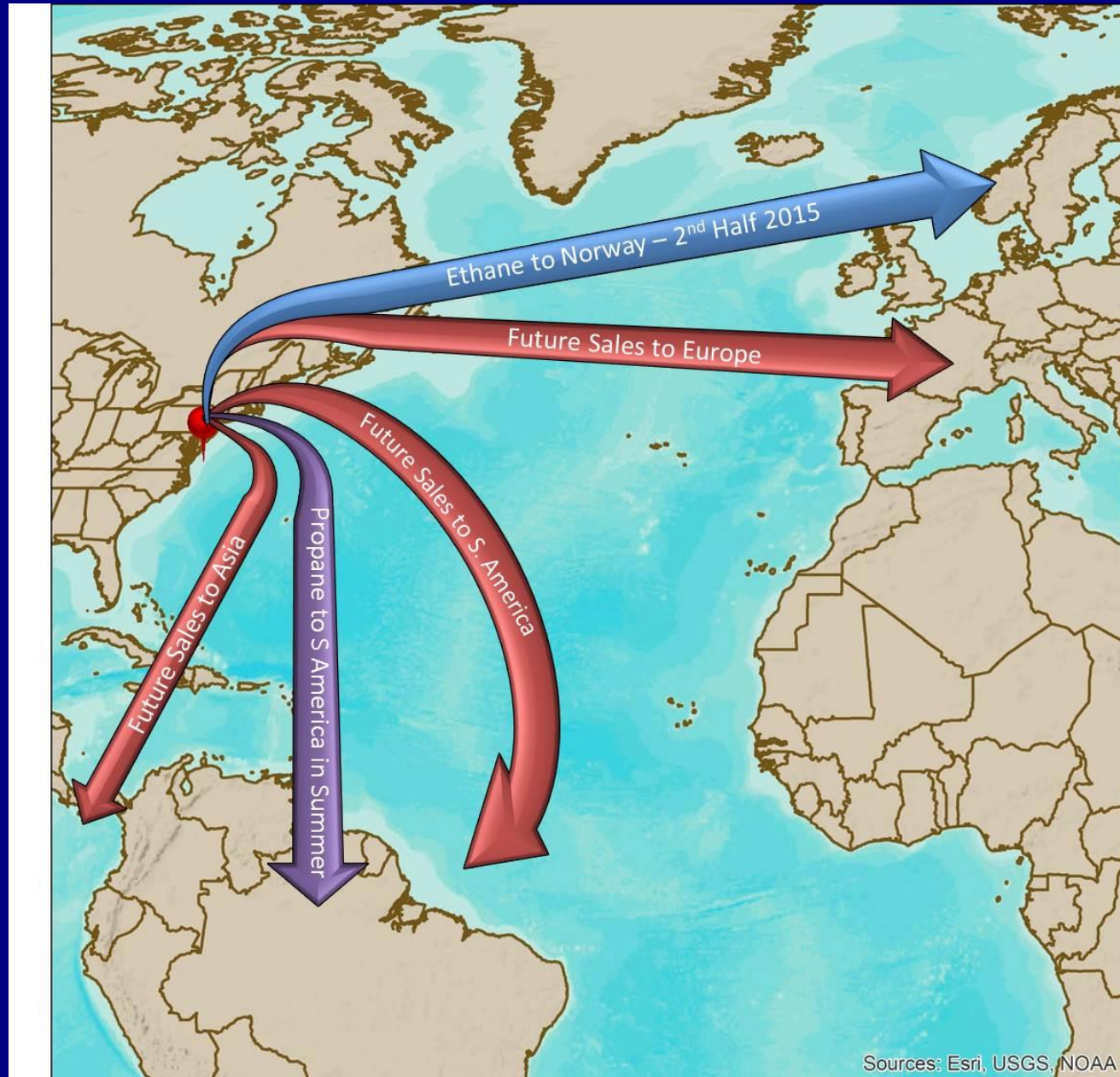
US NGL Pipeline System



U.S. NGL SUPPLY POTENTIAL ASSUMING SUFFICIENT MARKETS (MBPD)



US NGL - Now a Global Market



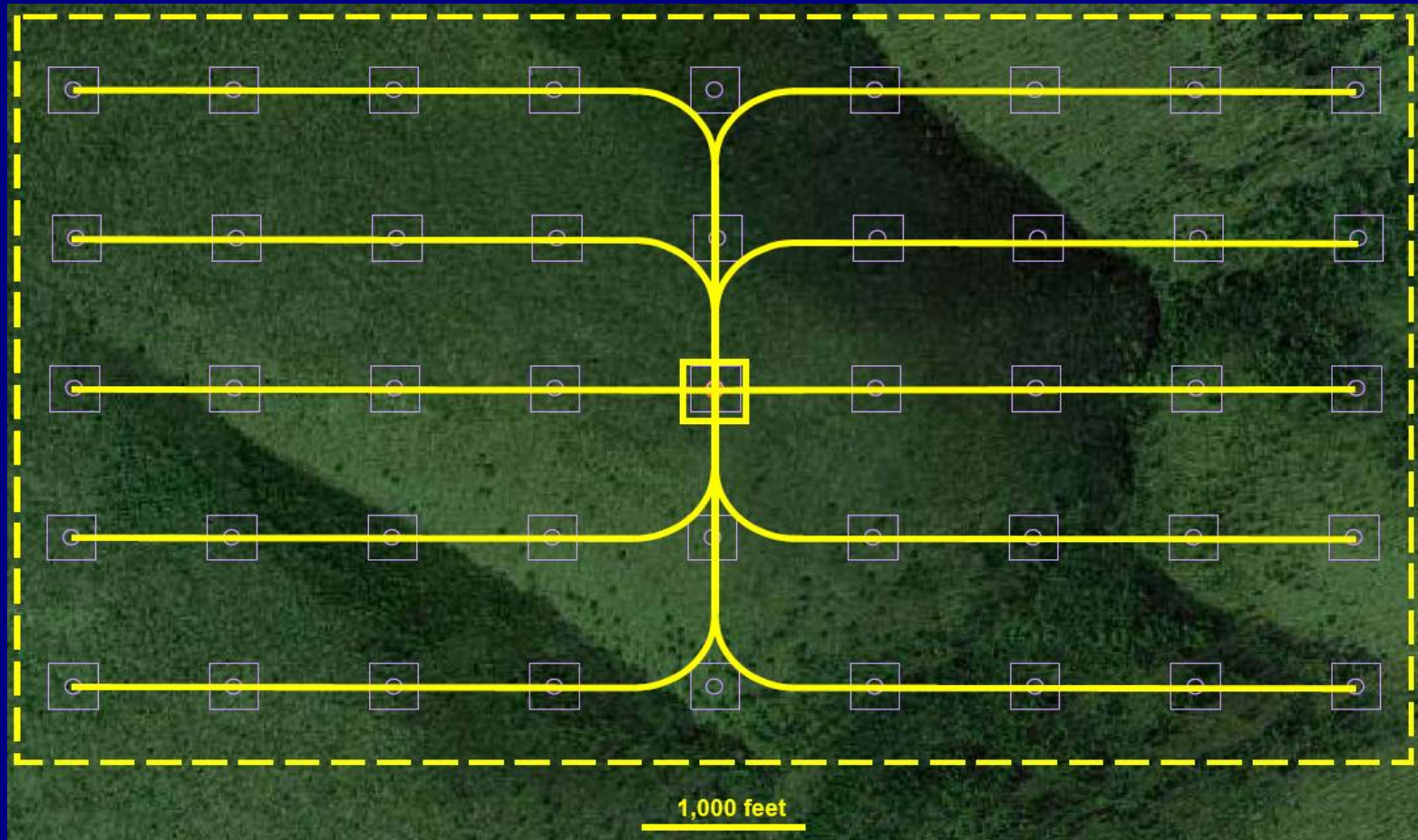
Developing New Shale Plays: Challenges

- Large acreage position with expirations
- Initial learning curve
- Lack of infrastructure & gas processing
- Lack of service providers, manpower, and equipment
- Changing regulations
- Opposition from local government & environmental groups
- Knowledge gap on hydraulic fracturing with public and academia

Technological Trends Spur Shale Development

- Accelerated positive results by:
 - Multiple wells from one pad
 - Core analysis and landing targets
 - Horizontal drilling efficiency gains
 - Completion advancements
 - Water management
 - 3D seismic and microseismic
 - Reducing vapor emissions
 - Advanced reservoir modeling

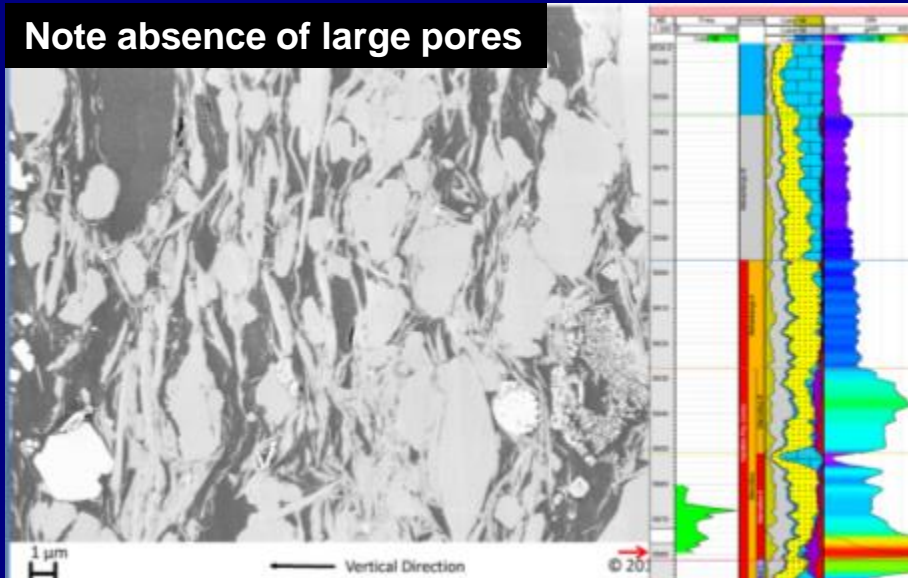
Pad Drilling Provides Many Benefits



- Horizontal surface disturbance is 1% on 1,000 acres
- Vertical wells on 1,000-foot spacing develops 23 acres per well with 19% total surface disturbance

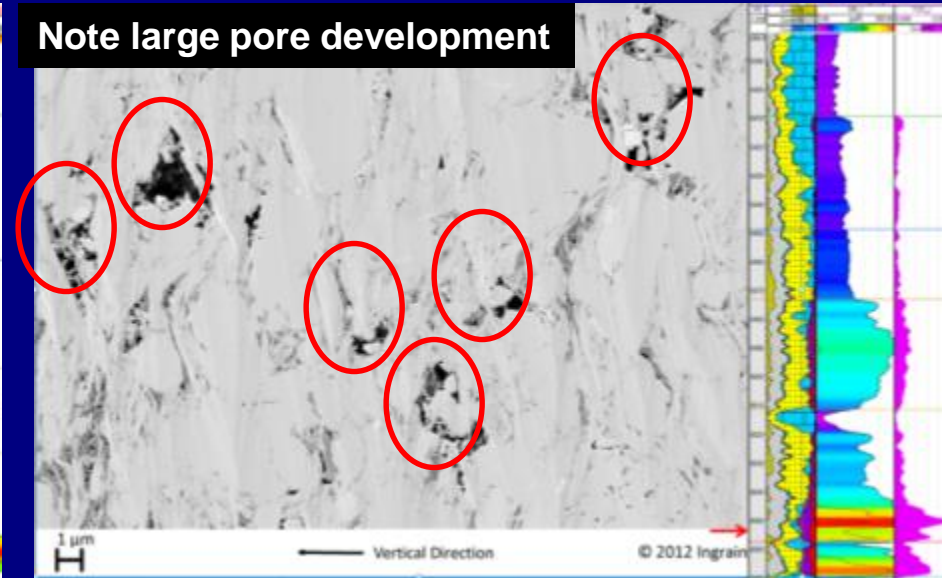
Comparison of Landing Targets and Focused Ion Beam/Scanning Electron Microscope (FIB/SEM)

Note absence of large pores



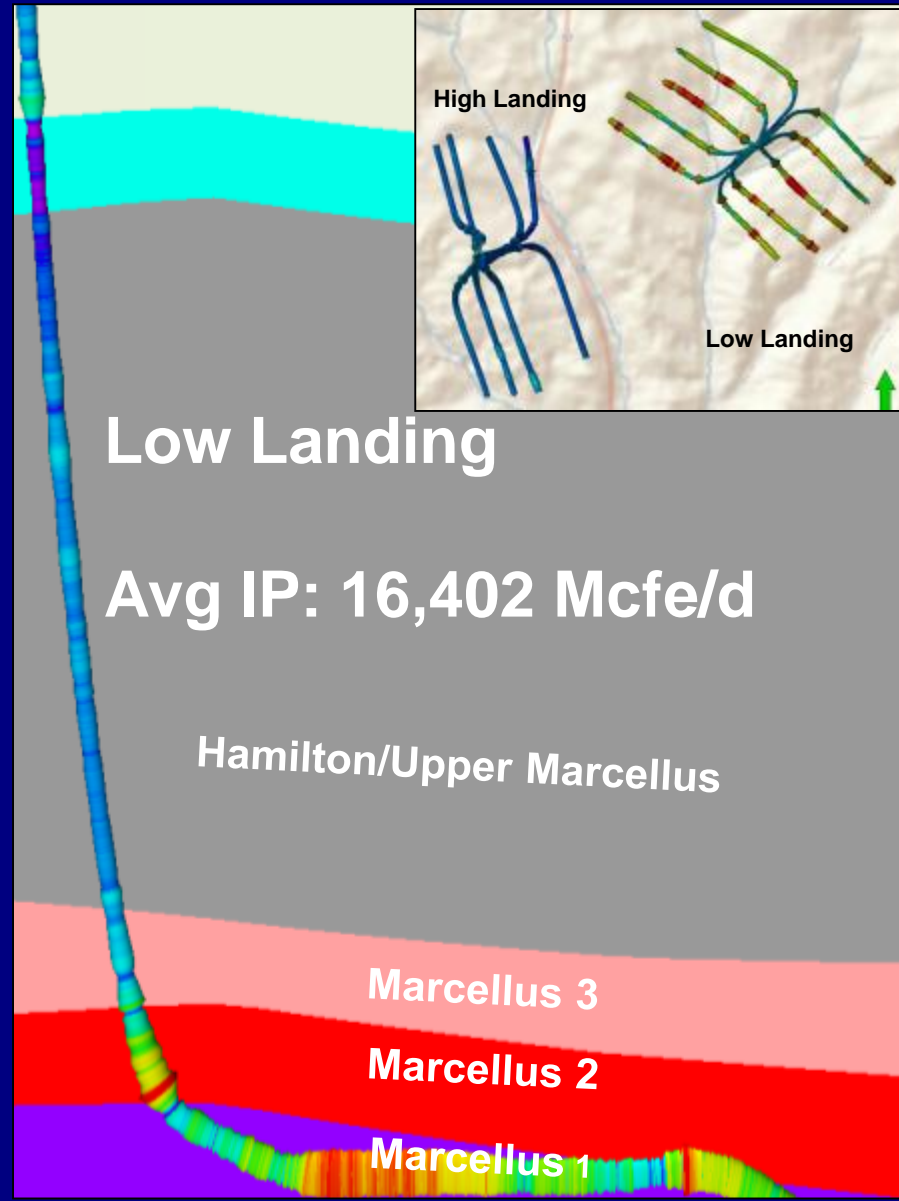
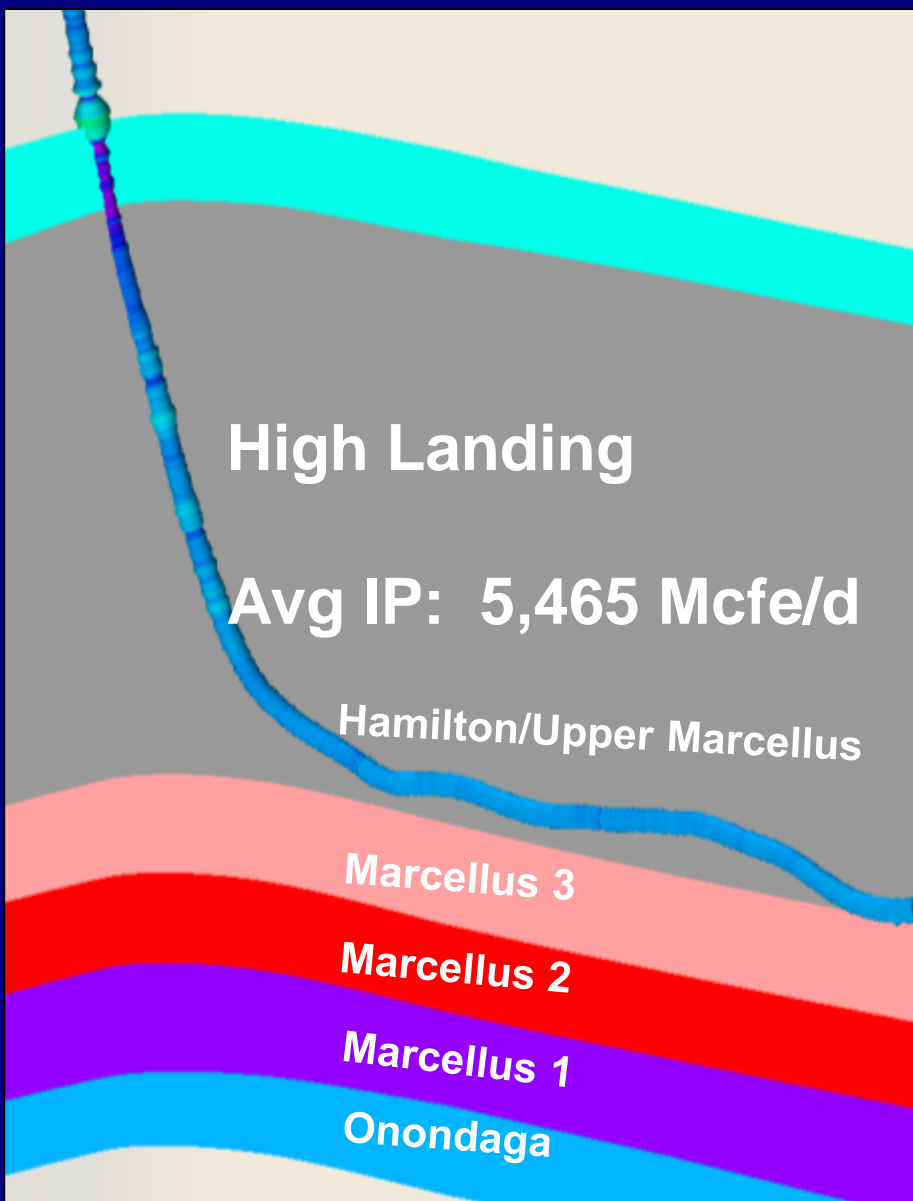
Well results disappointing

Note large pore development



Well results excellent

Better Production from Lower Landing Target

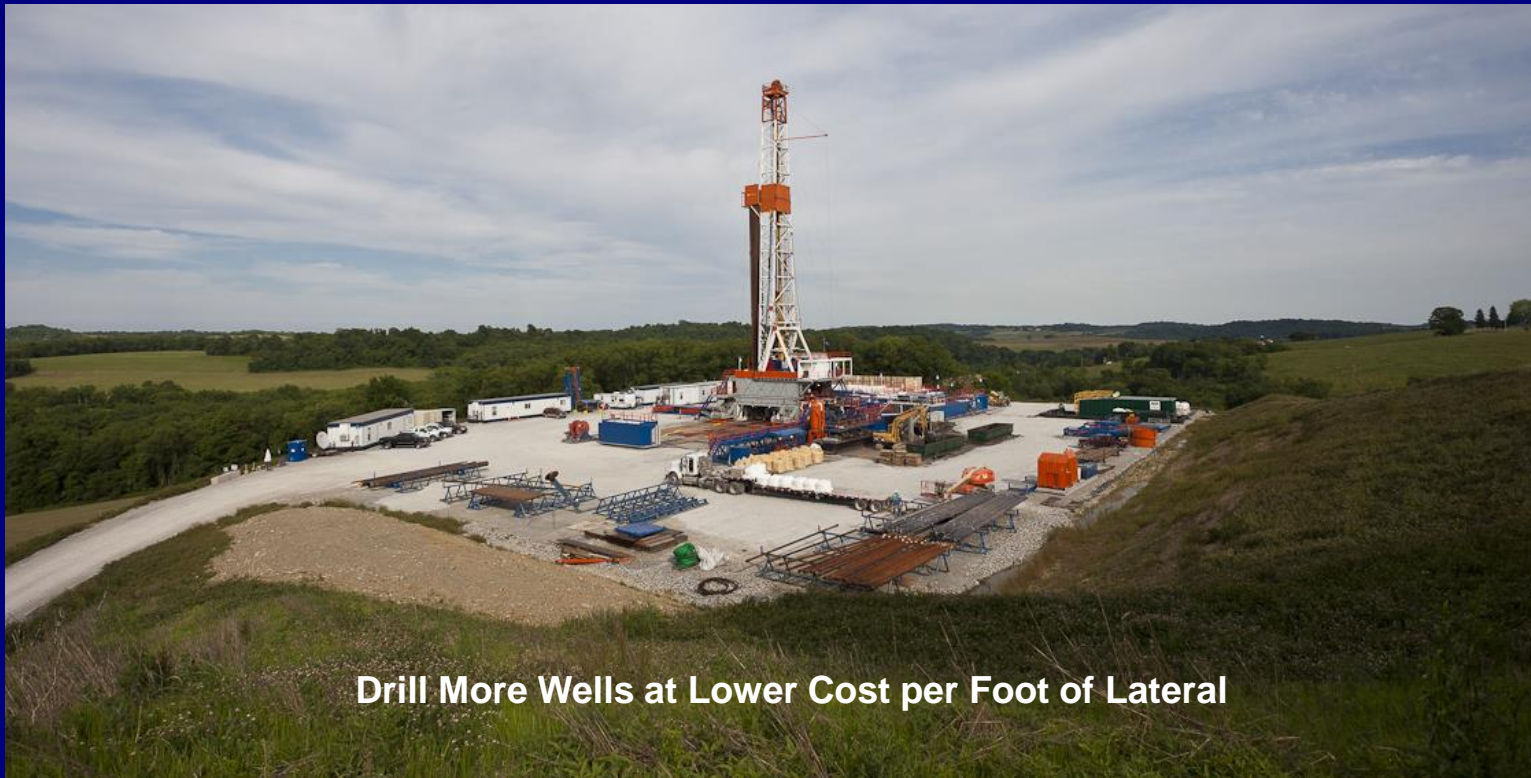


Keys To Drilling Success

- Continuous Drilling Program
- Stability of Personnel
- Focus On Key Performance Indicators (KPI's)
- Incentives
- Create and Maintain Team Atmosphere
- Constant Communication
- Continuous Improvement Focus

Drilling Improvements in Marcellus

	2010 # Wells Drilled/Year	2013 # Wells Drilled/Year
Air Rig	19	43
Horizontal Rig	18	29



Drill More Wells at Lower Cost per Foot of Lateral

Based On Range Resources in Southwestern Pennsylvania

Containment for Drilling and Completion



Well Construction Protects Ground Water

- Industrial process
- Multiple fully cemented strings of casing
- Over 3 million pounds of steel and cement
- 30 state and federal agencies monitor well construction and hydraulic fracturing processes



Water Storage and Transfer Has Improved



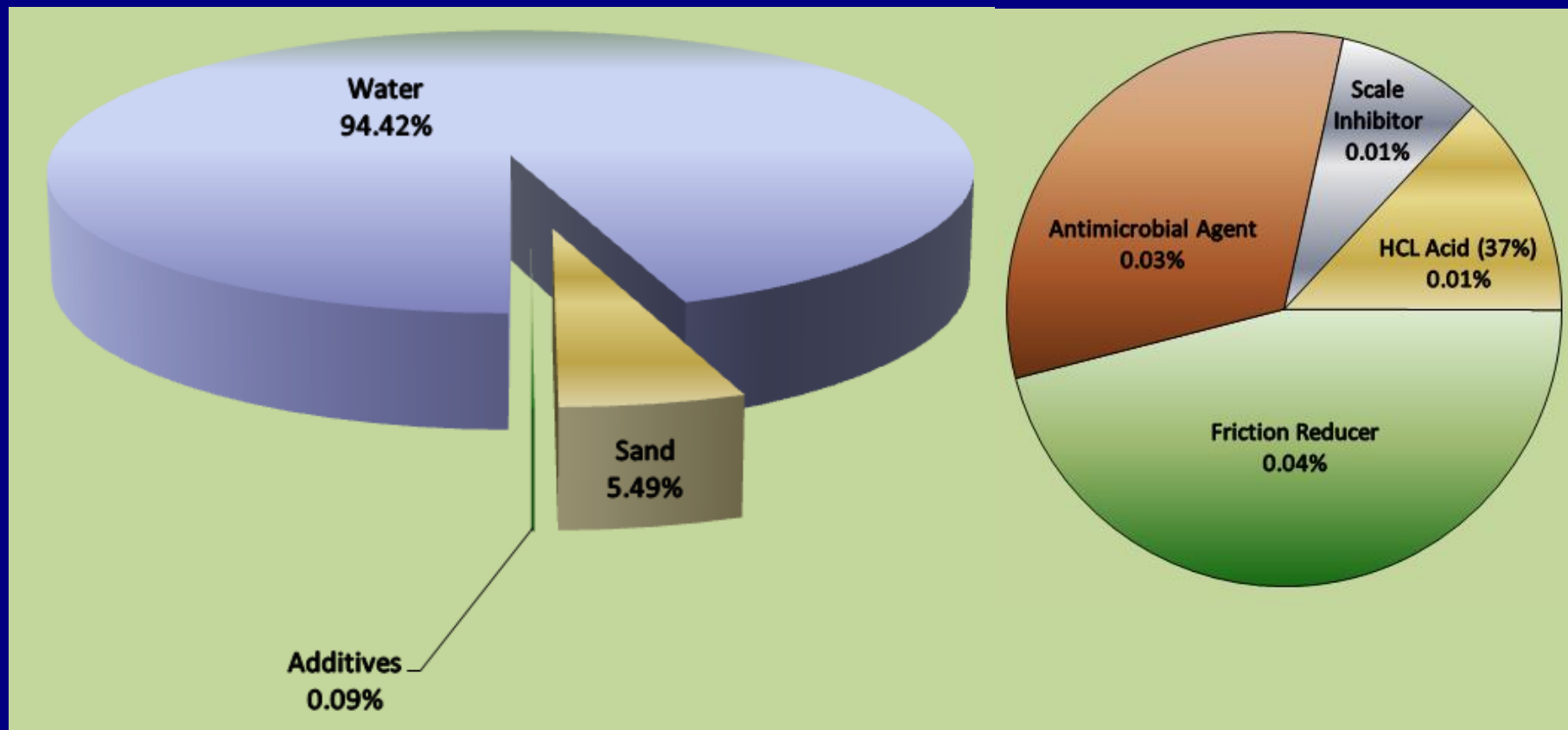
Completion Efficiency Continues to Improve

	2010	2013
Wells	75	121
Stages	744	2227
Stages/Day	3	6

100% More Stages Per Day from 2010 to 2013

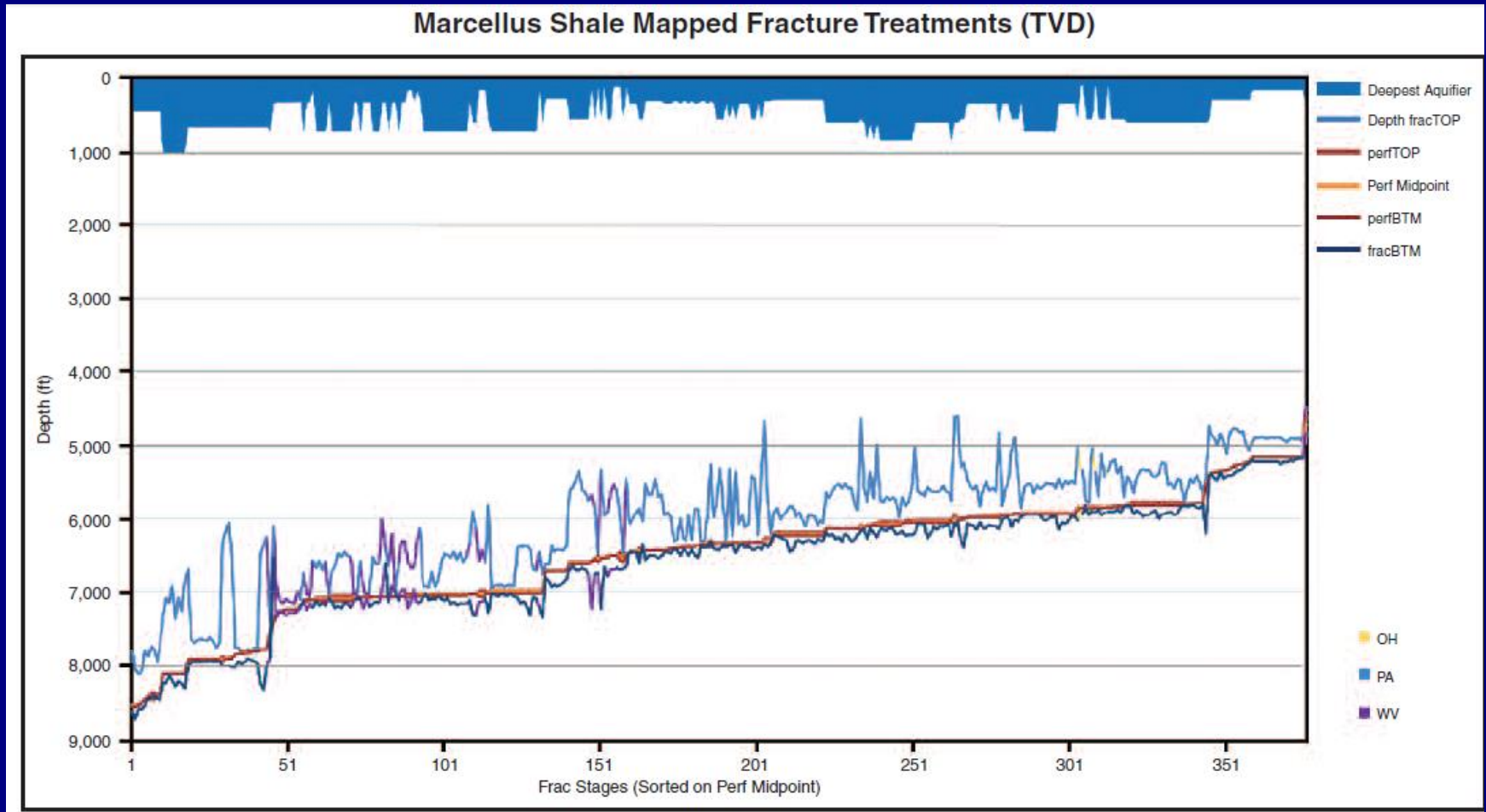


Constituents in Slick Water Treatments

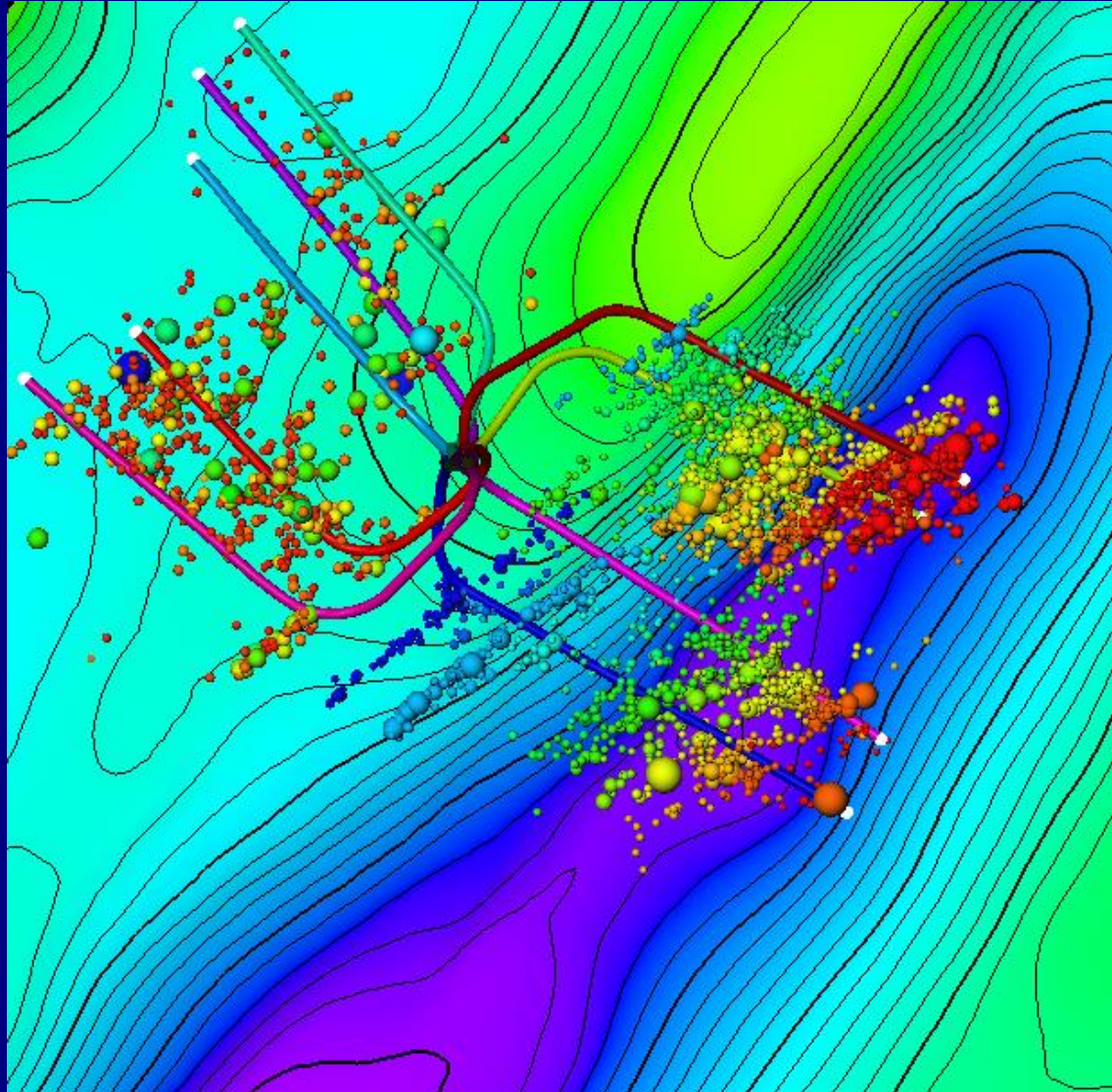


- Over 1 million wells fractured over the past 60 years in 27 states
- 90 percent of oil and gas wells are hydraulically fractured
- FracFocus used as national chemical registry database

Hydraulic Fractures Show Limited Height Growth Based on Microseismic Data Analysis

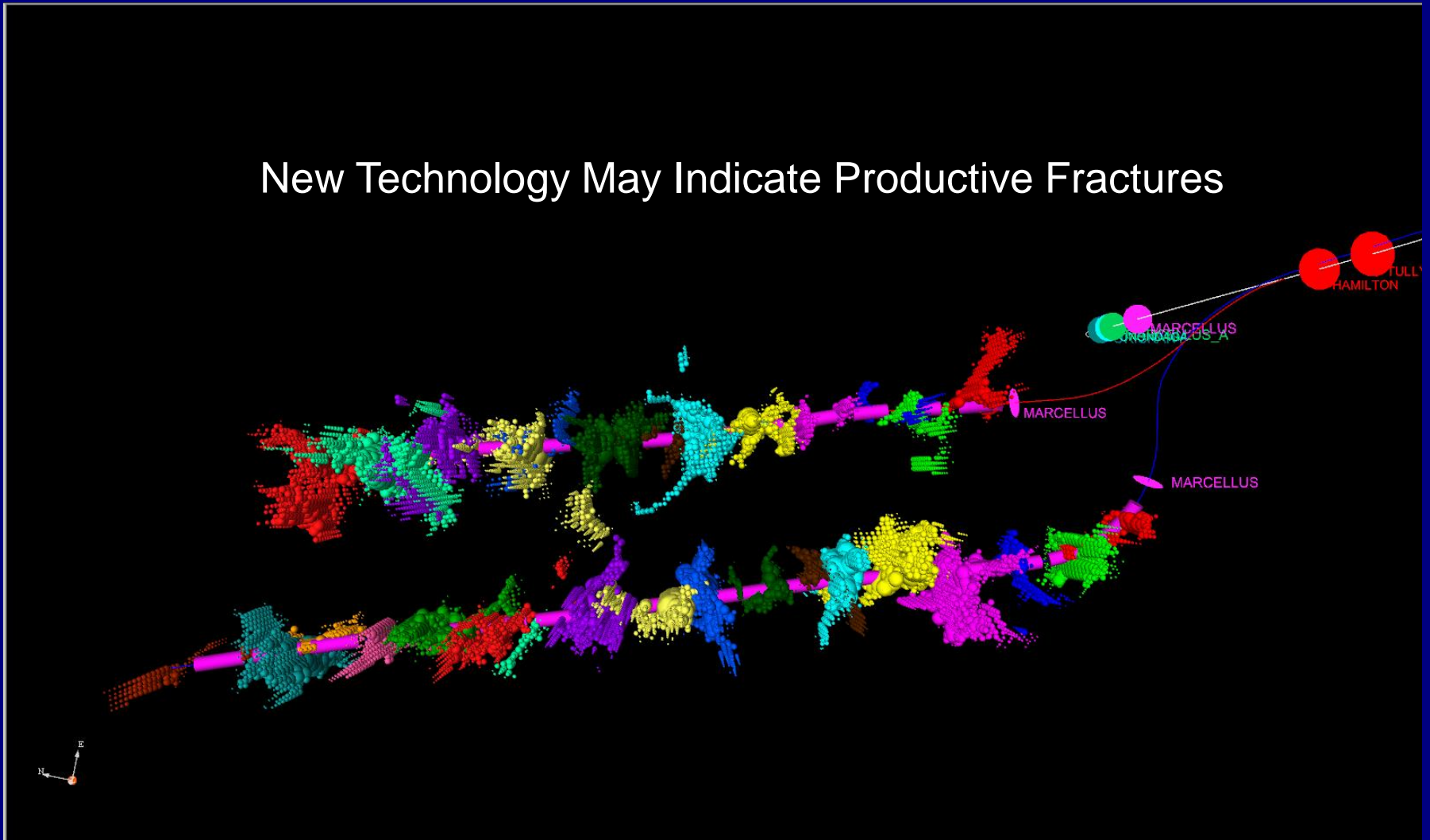


3D Seismic and Microseismic Used to Understand Geology & Fracture Geometry



Near-Wellbore Tomographic Fracture Imaging

New Technology May Indicate Productive Fractures



Near Well TFI (view from above)

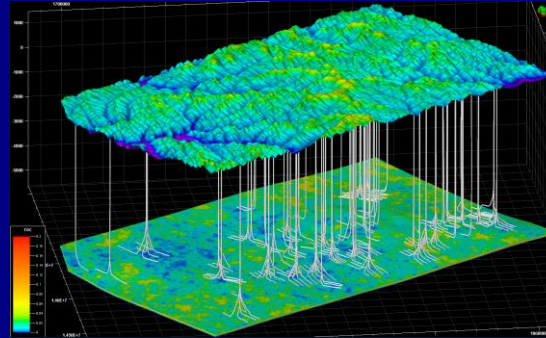
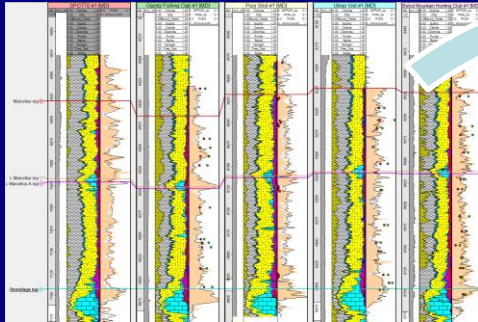
Facility Improvements Reduce Emissions



Workflow Overview for Analytical Reservoir Models

3D Geologic Model

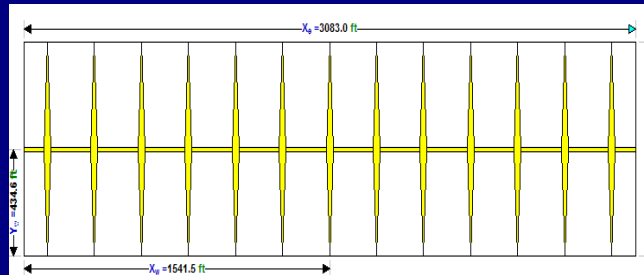
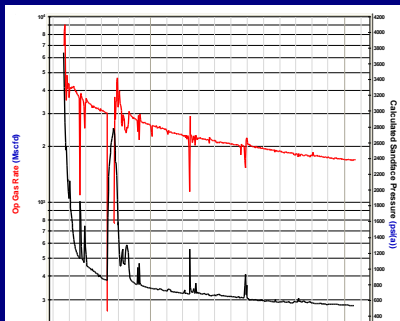
Logs and core



Reservoir Properties

- Reservoir Pressure
- Reservoir Temperature
- Thickness
- Porosity
- Saturation
- Adsorption Parameters

Rates and Pressures

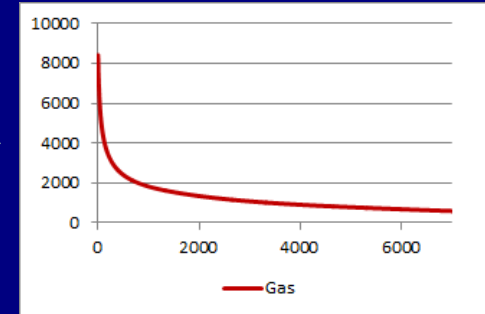
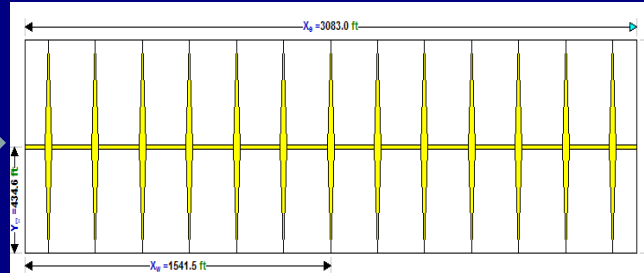


Model Stimulated Zone

- Completion Stage Length
- Number of stages

Reservoir Modeling to Evaluate Outcomes

$$\frac{1}{r_D} \frac{\partial}{\partial r_D} \left(r_D \frac{\partial p_D}{\partial r_D} \right) = \frac{\phi \mu c_i r_w^2}{k} \frac{\partial p_D}{\partial t}$$



The 4 L's

Long Laterals

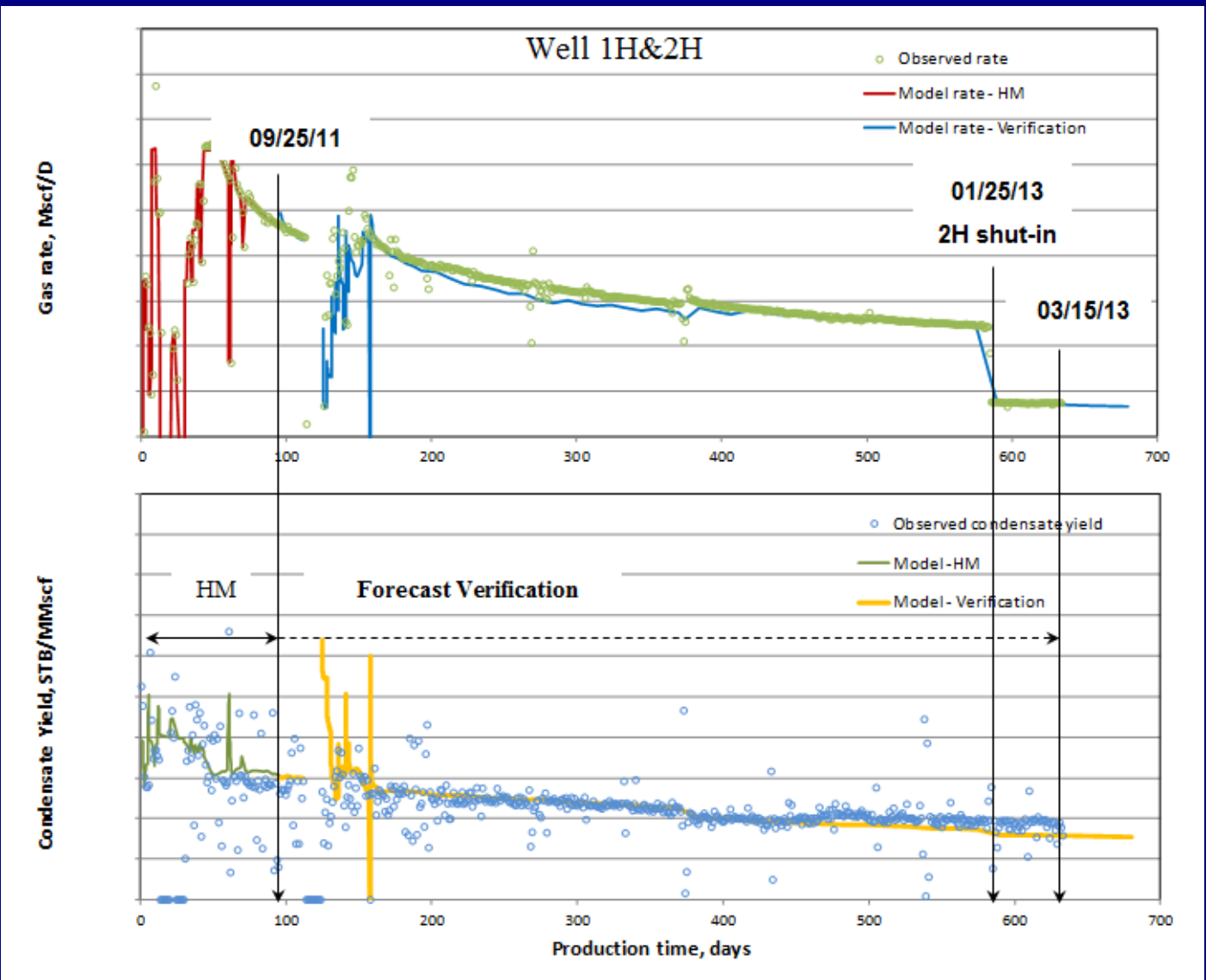
Limit Stage Length

(Reduced Cluster Spacing)

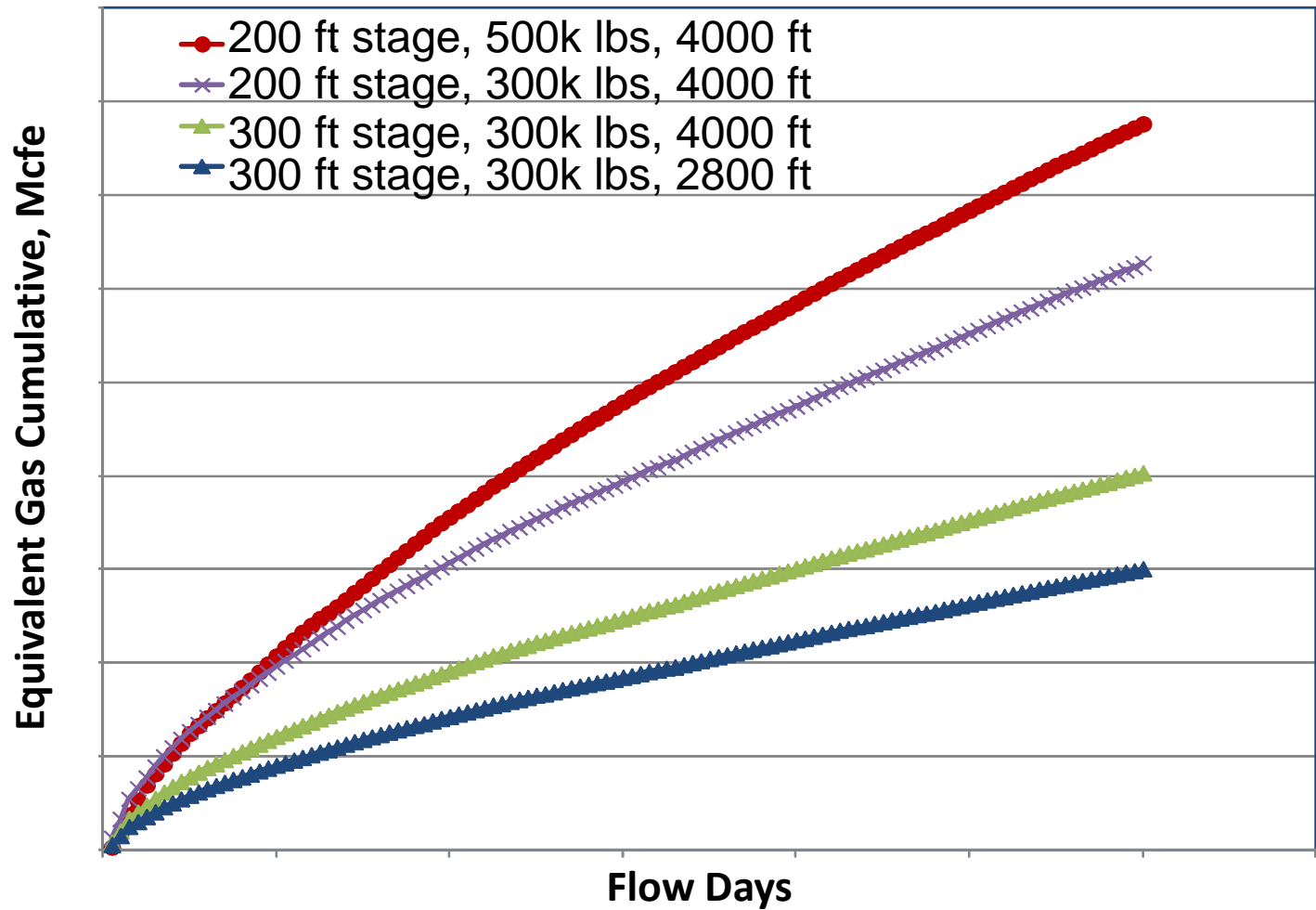
Land Properly

Load With Appropriate Sand

Reliable Forecasts from Calibrated Reservoir Models

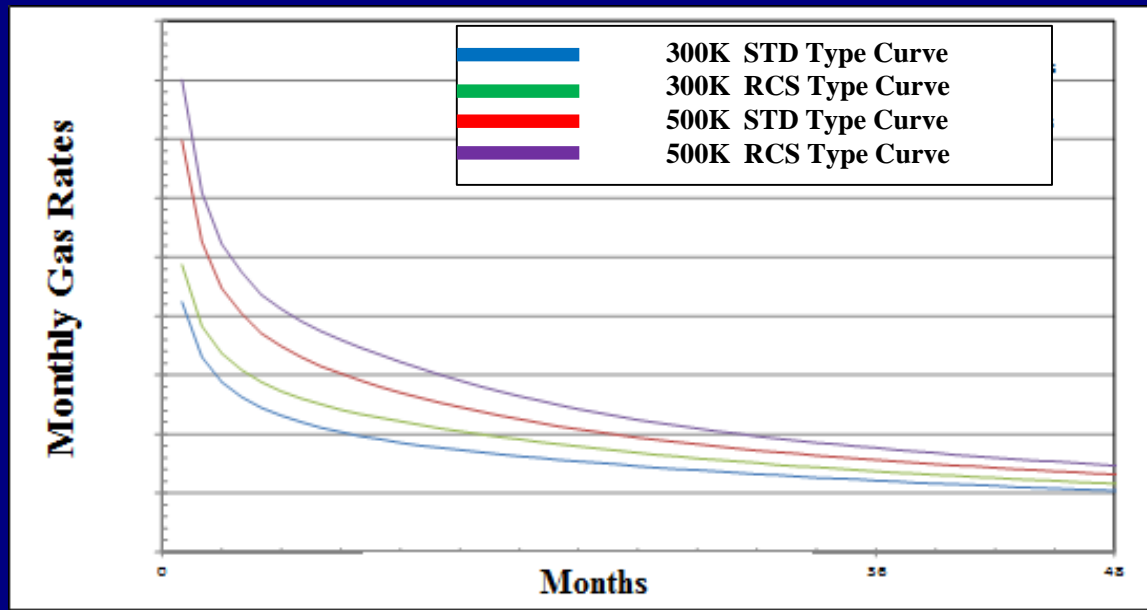
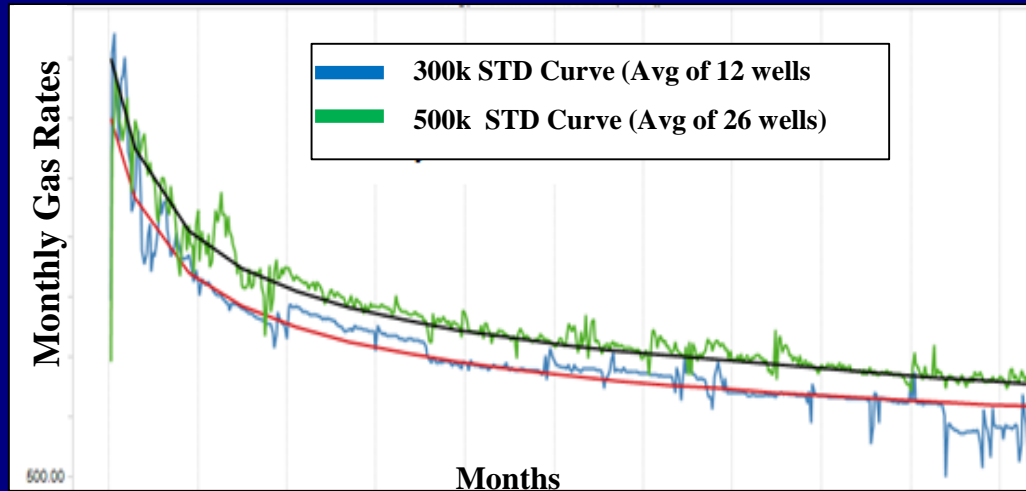


Production Improves with Longer Laterals and More Stages



Range Resources data in Marcellus wet gas area of Washington PA.

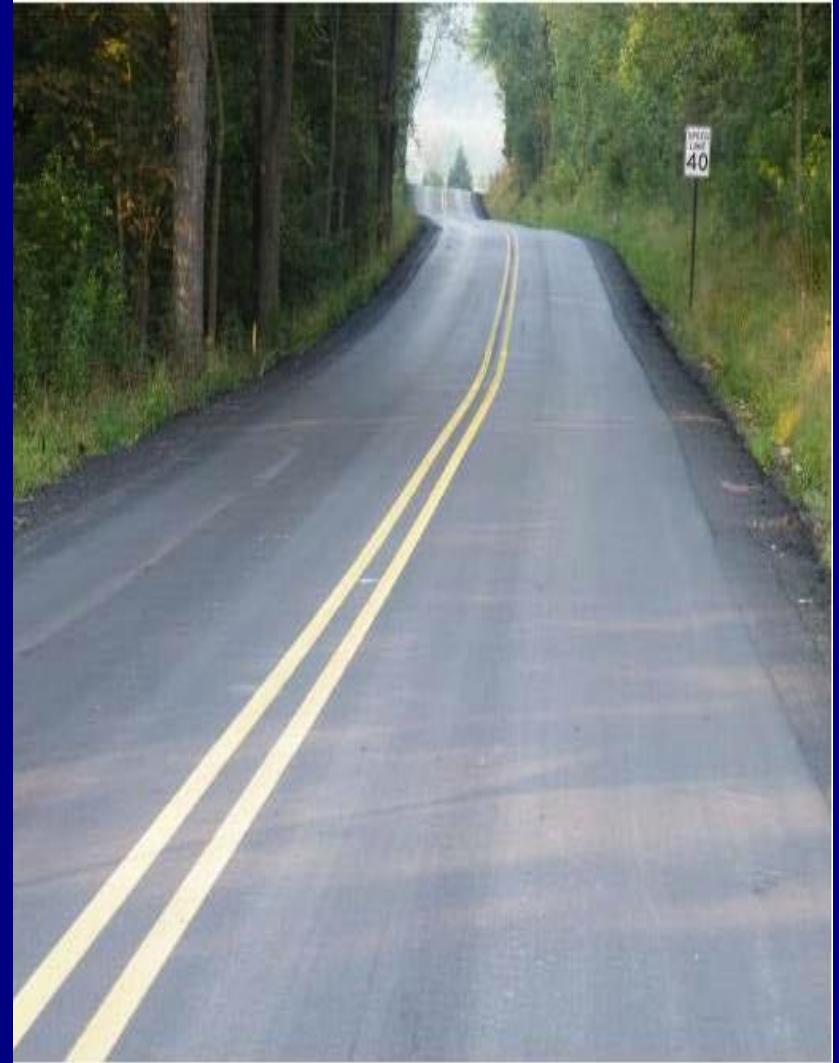
Developing Base Type Curve & Applying Uplifts



Operators Improve Roads (\$1 Billion) and Pay Fees and Taxes (\$2.7 Billion) in Pennsylvania



Before



After

Safety Training

- First Responders
 - 3500 trained
 - 69 sessions
 - 40 counties
 - Permanent funding under Act 13
- Transportation Safety
 - Transportation Day
 - PA State Police
 - Department of Transportation
 - Public Utility Commission
 - Department of Environmental Protection



MARCELLUS SHALE COALITION™

**MARCELLUS SHALE SAFETY PROGRAM
FOR PENNSYLVANIA'S FIRST RESPONDERS**

Pennsylvania's first responders are on the front lines of public safety during a variety of emergencies, including rare emergencies involving Marcellus Shale operations. The Marcellus Shale Coalition (MSC) and its member companies are dedicated to ensuring these men and women have the training they need to improve safety on production sites—and throughout their communities.

Members of the MSC seek to provide the safest possible workplace for their employees, while remaining committed to being responsible members of the communities in which they work. These are Guiding

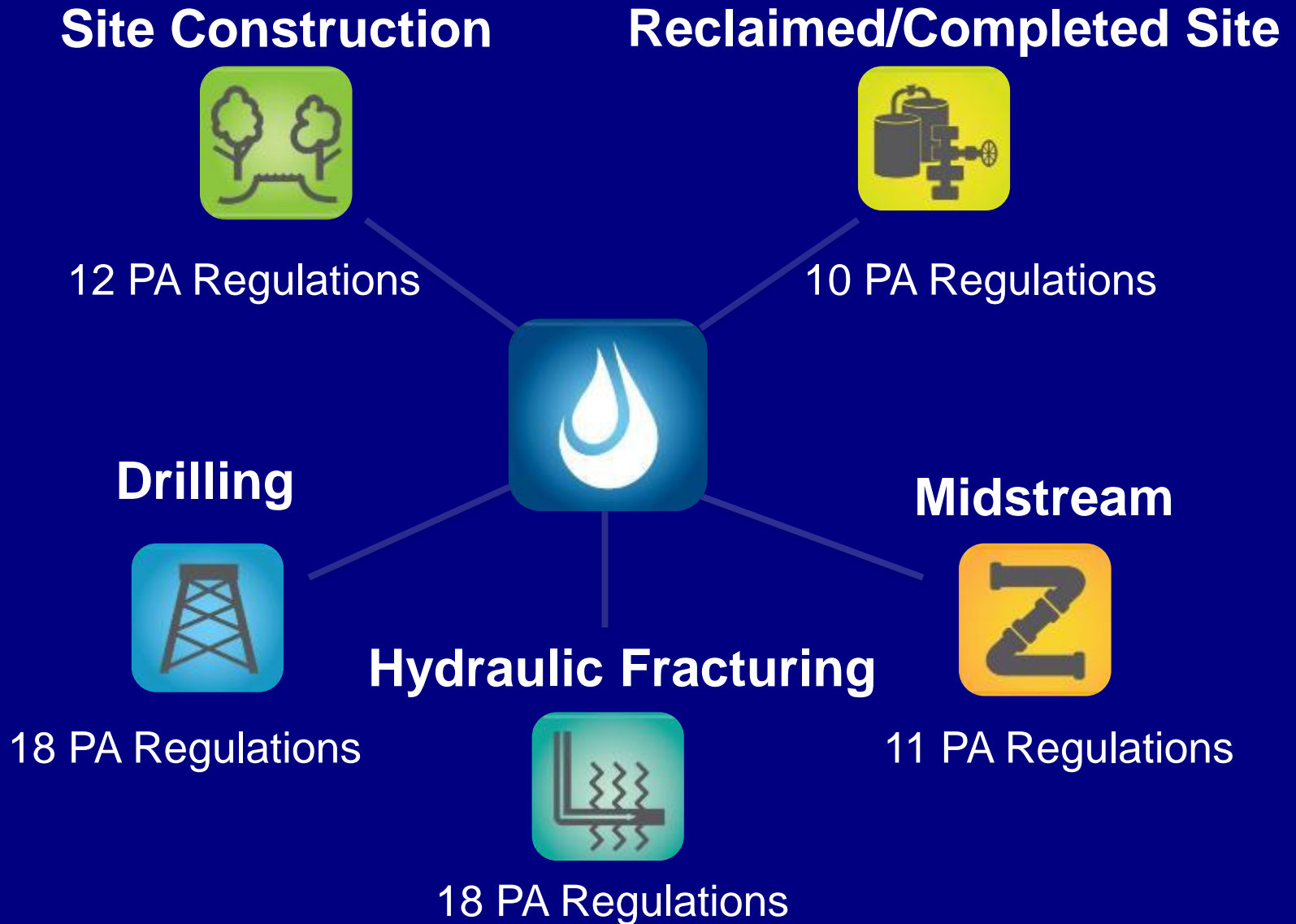
By the Numbers:

3,000+
Volunteer firefighters trained

58



State Regulatory Framework

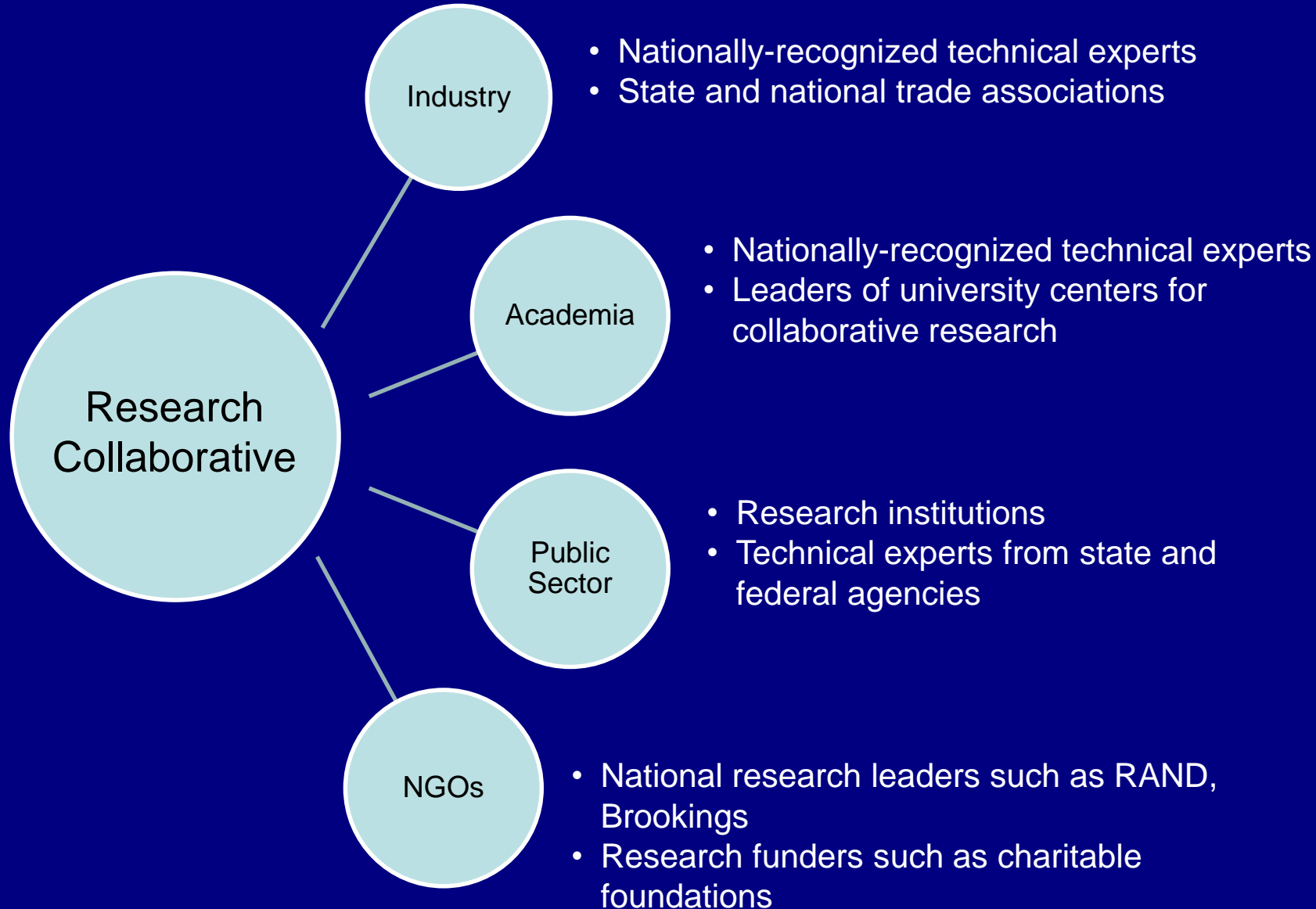


Significant Regulatory Framework Already In Place



Scene in film: **FRACKNATION**

Research Collaborative



Public and Consumer Benefits

Water Usage



Utility Savings



Surface Impact



Air Quality



Manufacturing



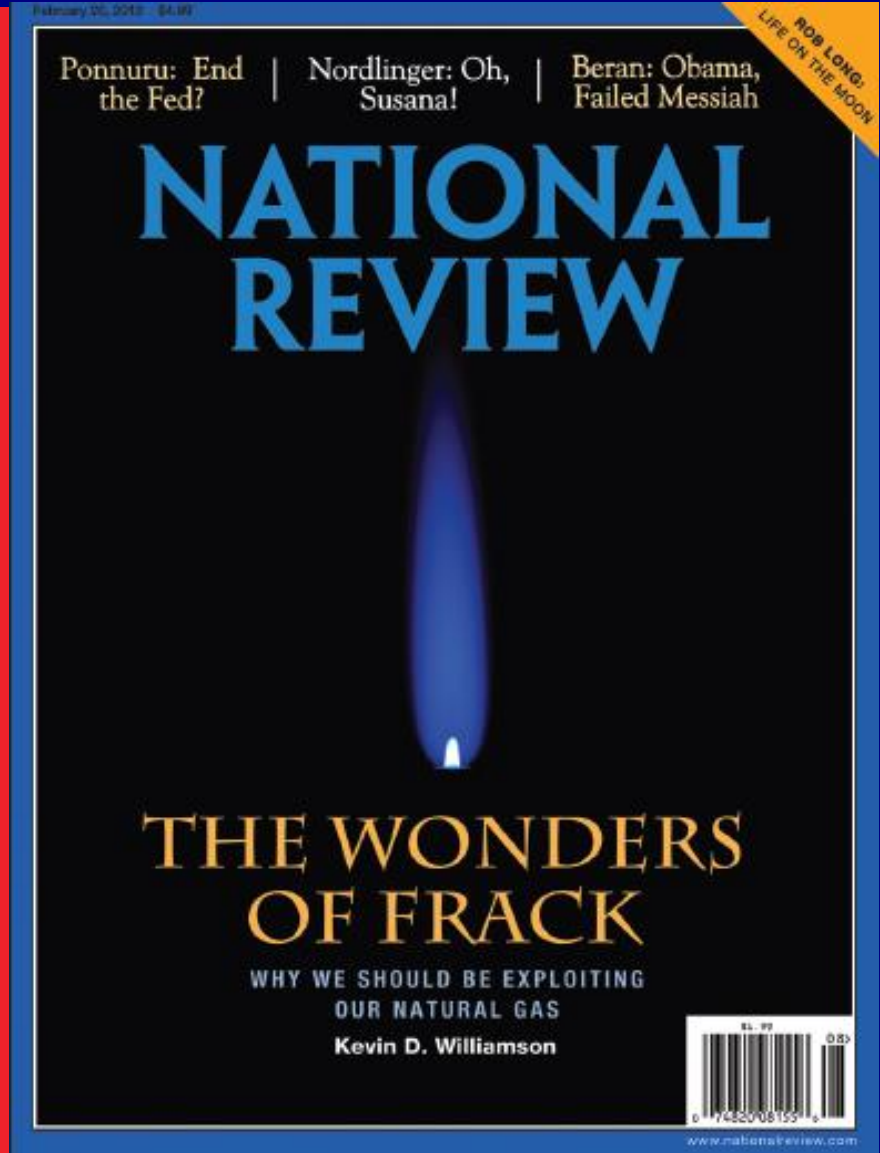
Transportation



Family-Sustaining Jobs



The Shale Gas Revolution is Global



Summary

- Opportunities and challenges abound
- New technology and efficiency gains continue to thrive
- Industry is working with stakeholders to reduce its footprint and environmental impact
- Natural gas provides an abundant and long term source of cleaner burning fuel that creates jobs

Thank You!

Questions?

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Your Feedback is Important

Enter your section in the DL Evaluation Contest by
completing the evaluation form for this presentation

<http://www.spe.org/dl/>



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