What is Next in the Shale Energy Revolution?

Dave Yoxtheimer, PG

Hydrogeologist

Penn State Marcellus Center for Outreach and Research

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United States Energy Association

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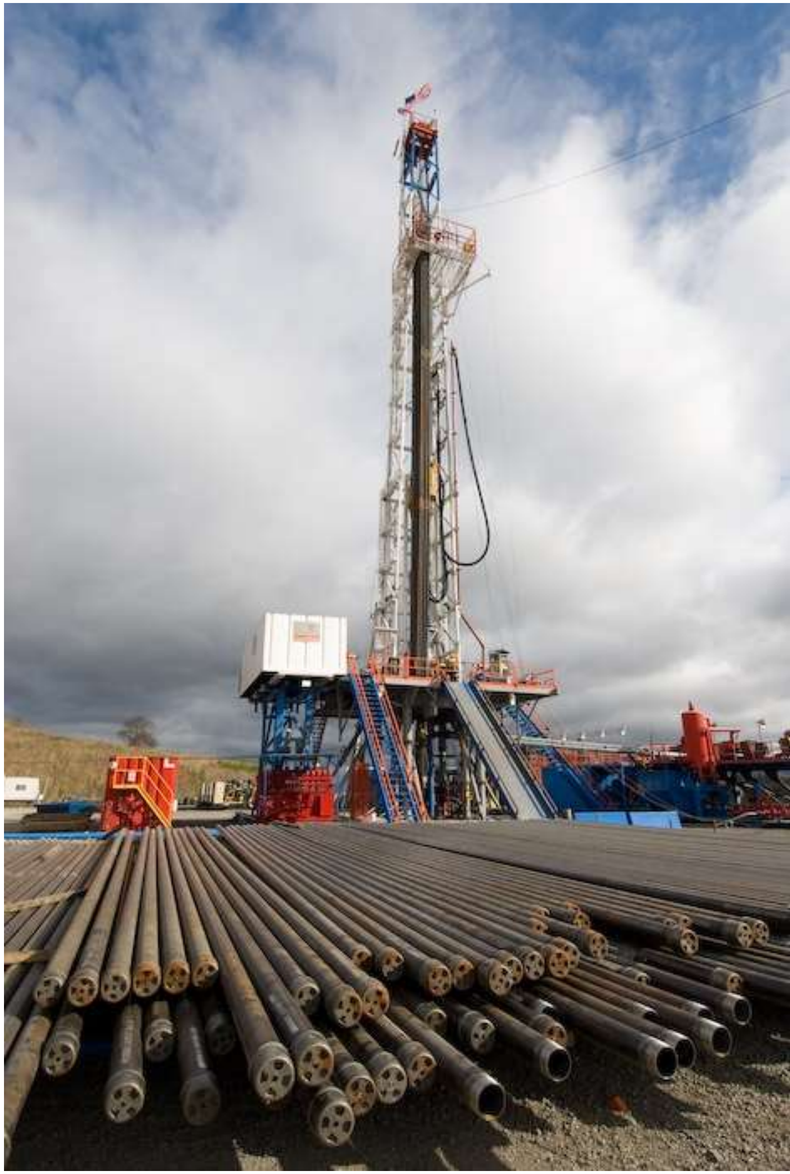
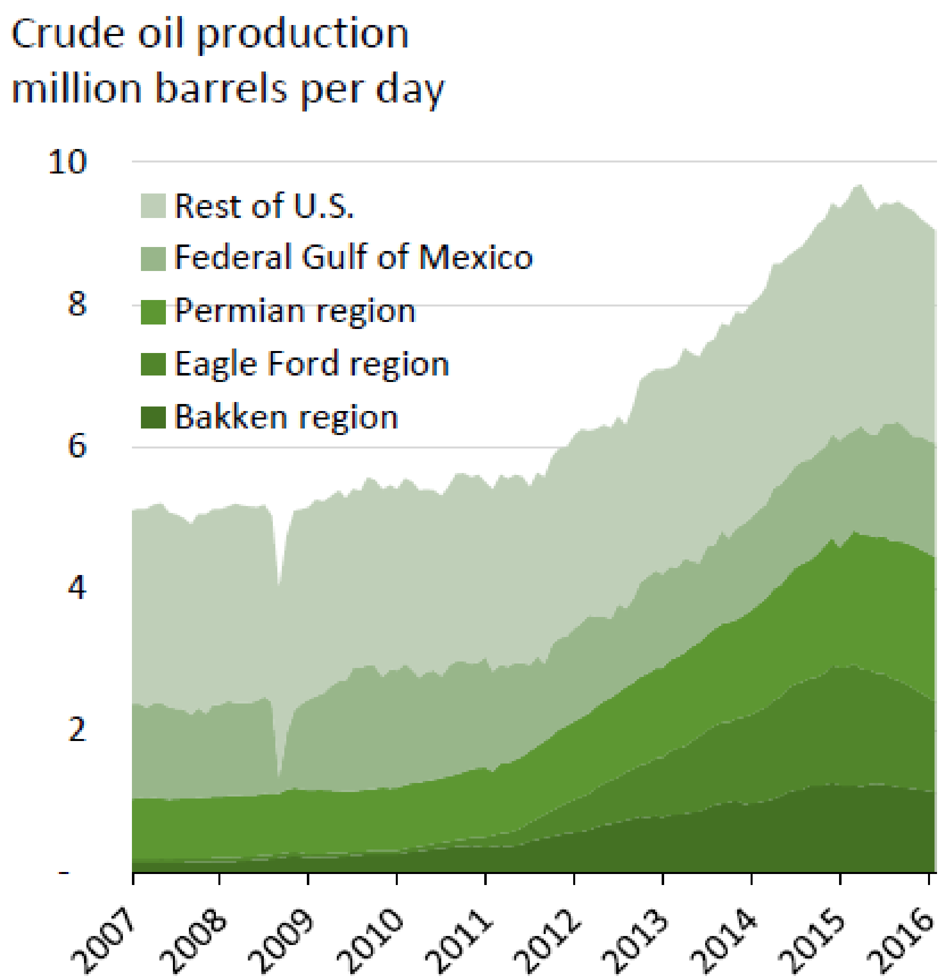
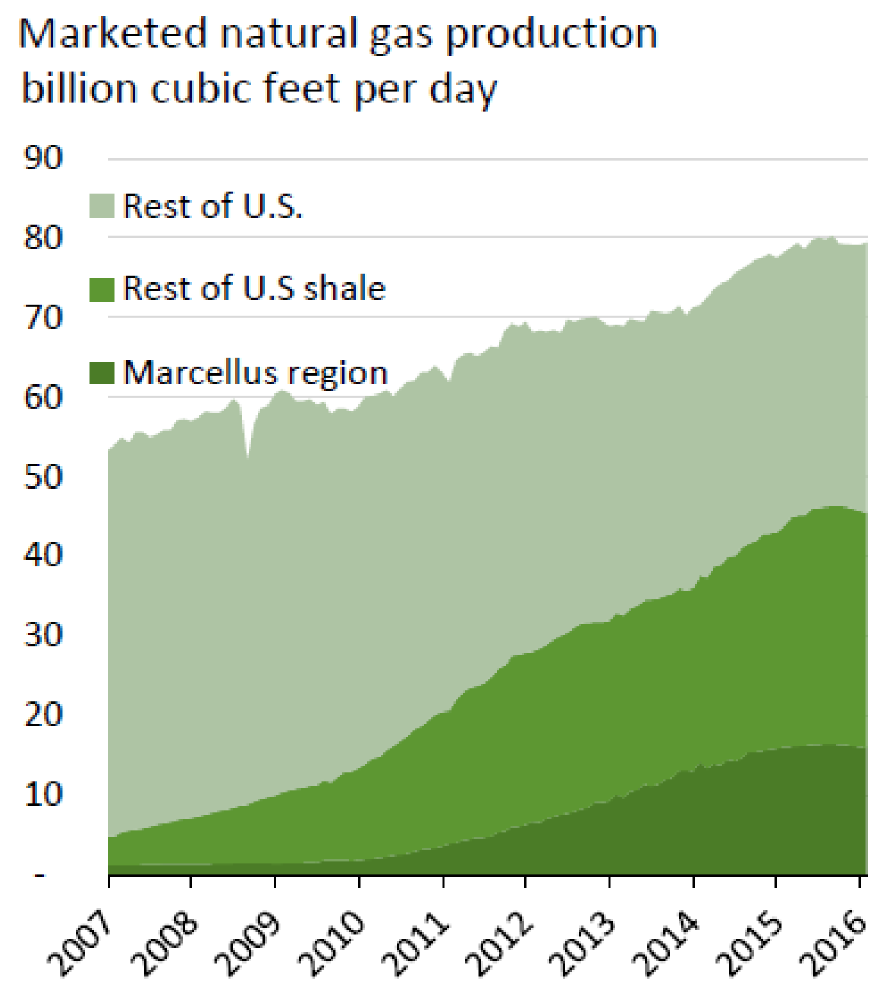
Shale Resource Supply Topics

- Improving geologic characterization
- Advancing drilling and fracturing technologies
- Optimizing recovery and production
- Decreasing development costs
- Minimizing environmental impacts
- Increasing downstream utilization



Unconventional Energy Driving US Oil and Gas Production Growth





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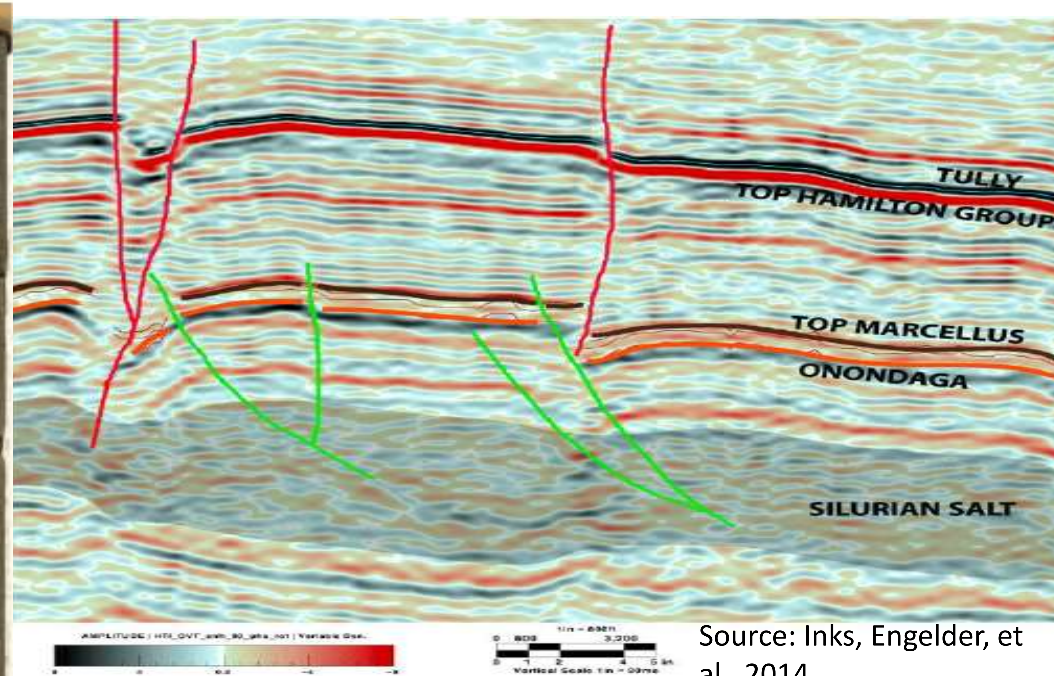
Source: EIA

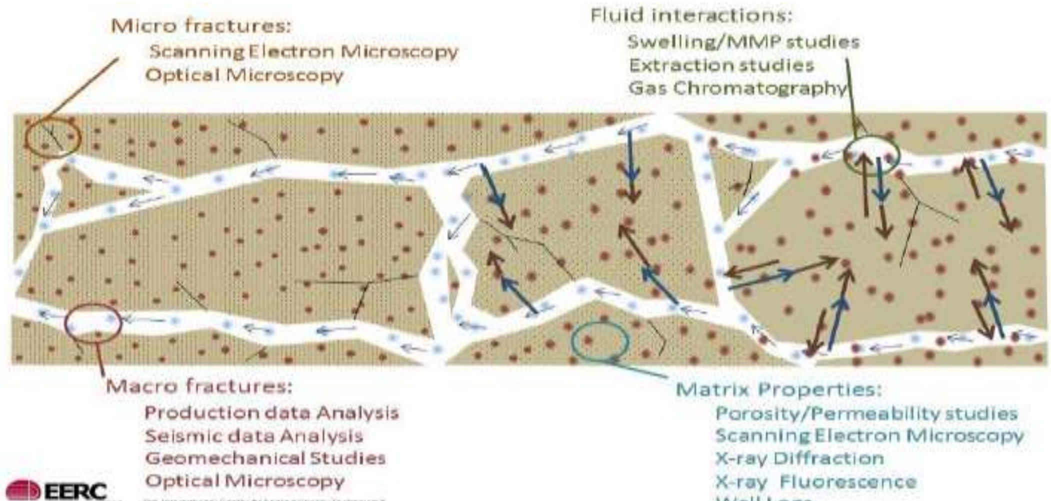
Improved Geologic Characterization

Seismic surveys allow an area's geologic setting to be characterized on a macro-scale to identify reservoir targets' depth, thickness, seals, and presence of faults and choose best drilling locations and orientations to increase recovery efficiency and optimize production

Innovations in micro-scale reservoir rock analysis reveal hydrocarbon content, fracture patterns, matrix porosity, and mineralogy to increase recovery efficiency improvements via drilling into higher quality rock, selecting most productive intervals for fracturing, and optimizing fracturing fluid formulations



Source: Inks, Engelder, et al , 2014



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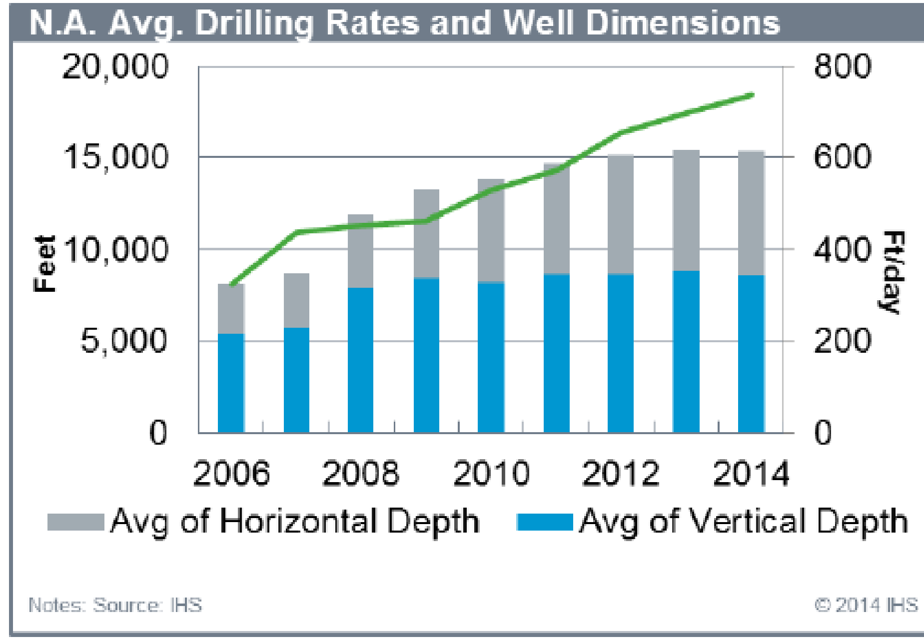
Increasing Drilling Efficiency and Reducing Emissions

Drilling rate efficiencies have doubled in the last decade thus reducing drilling time and rig costs. A typical shale well can be drilled in about 2 weeks.



A natural gas-powered drilling rig can reduce annual fuel costs $660K-$1MM off the annual fuel cost of one rig thus realizing up to 80% savings using field gas and reducing emissions.


Source: EQT Corp

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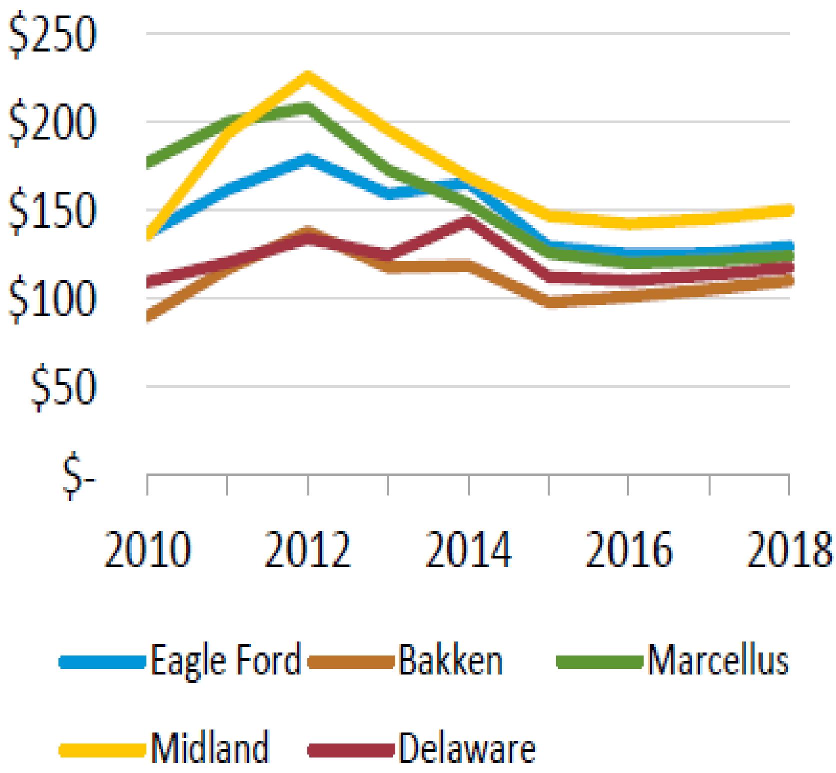
Drilling and Completion Cost Reduction

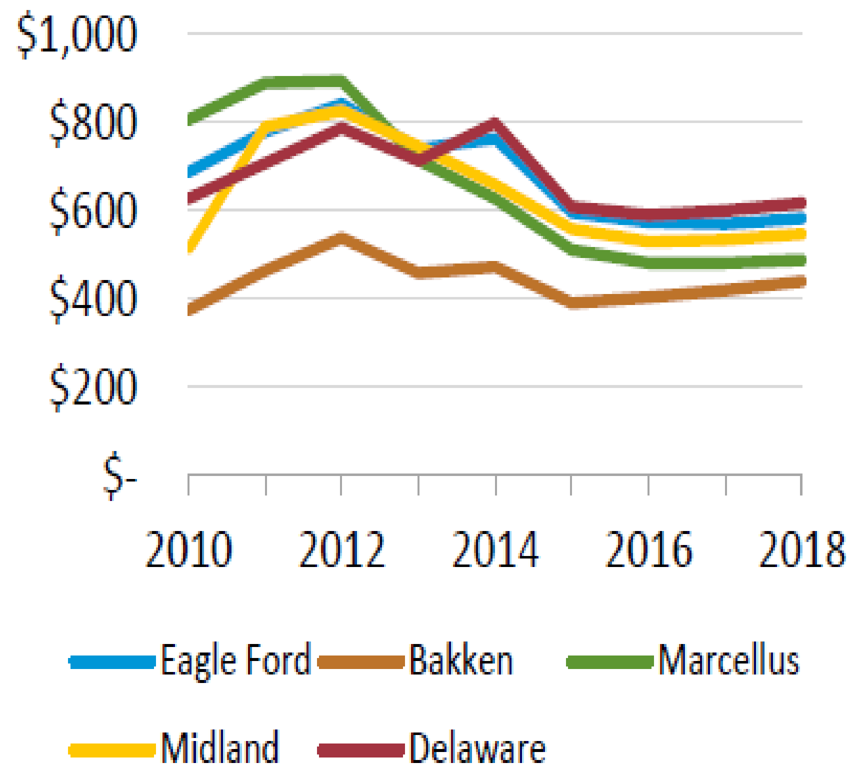
Drilling Cost per Total Depth

$ per foot



Completion Cost per Lateral Foot

$ per foot



Source: EIA, 2015

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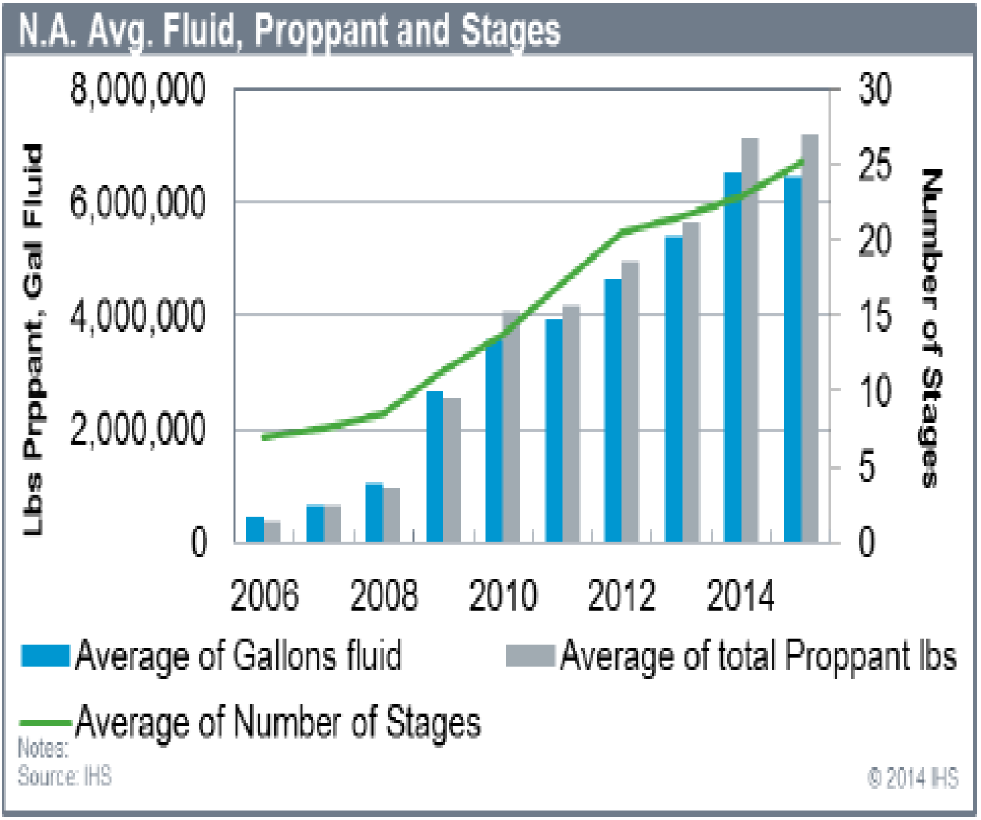
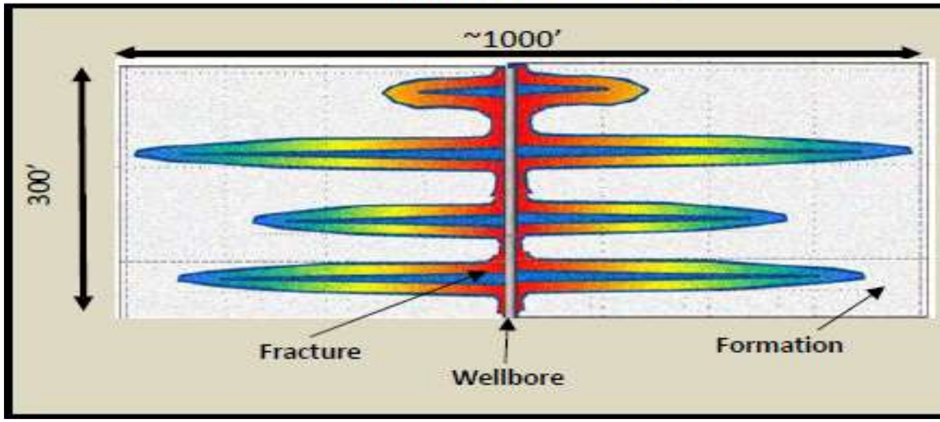
More Effective Fracturing Techniques

-Longer horizontal wells combined with more fracturing stages having shorter lengths and reduced cluster spacing increase the stimulated reservoir volume in a well

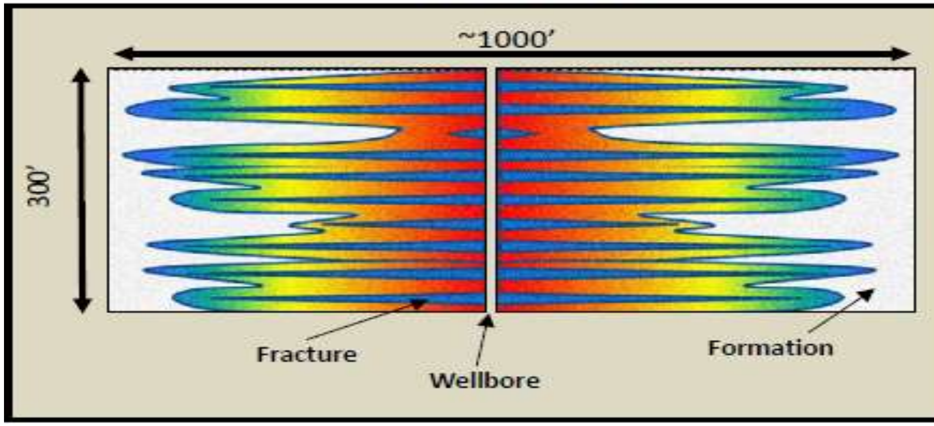
-Increased proppant and fracturing fluid volumes to stimulate longer well laterals



Conventional Design



RCS Design



Source: Seneca Resources

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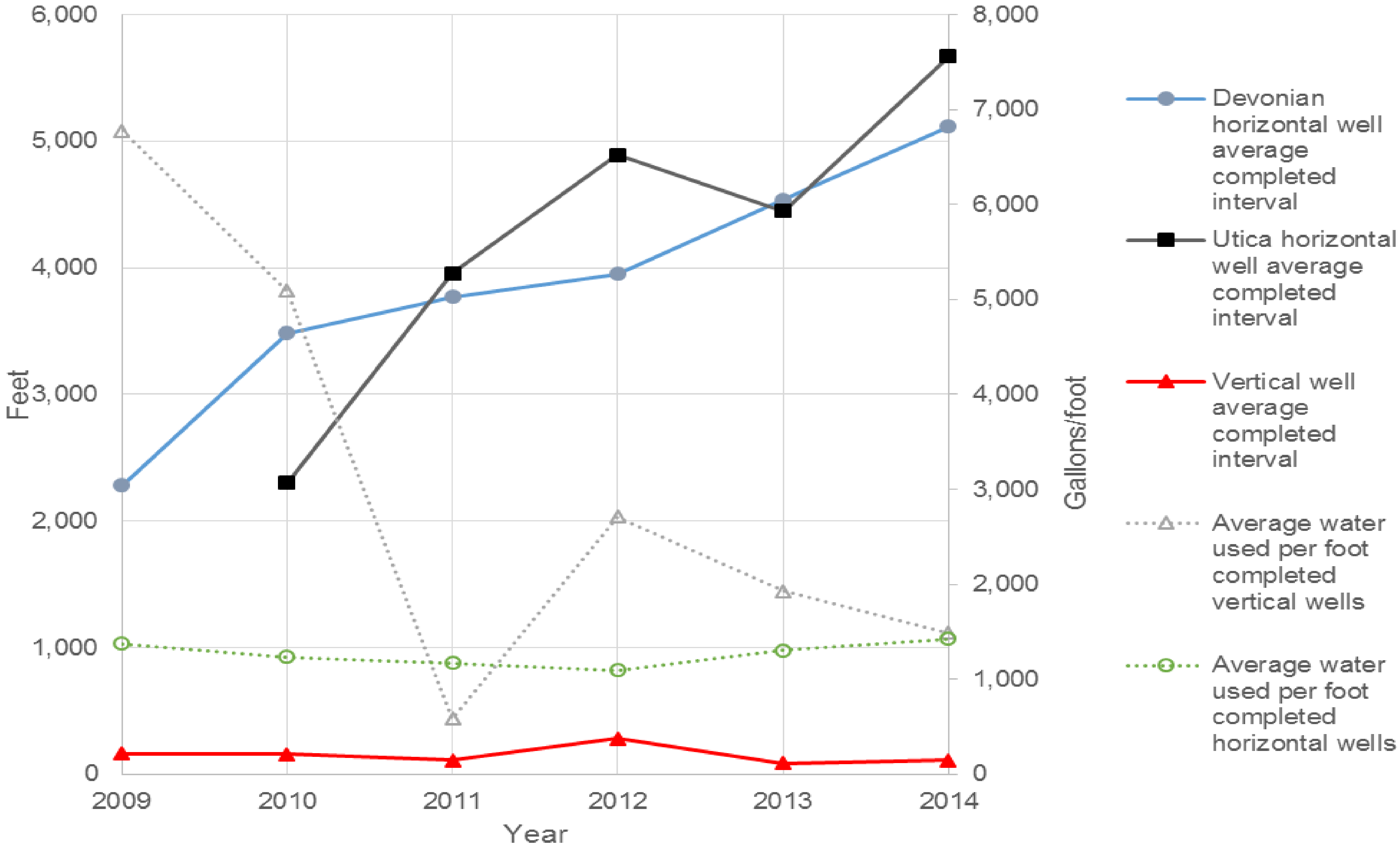
Well length vs water use per foot in PA



Schmid and Yoxtheimer, 2015

Efficient Shale Fluid Management Practices




- Fluids management costs range from 5-25% of shale energy development costs
- Efficient water sourcing, transport, storage, and fluids treatment keep costs down and are more environmentally sound
- Recycling of produced fluids for hydraulic fracturing is a key economic and environmental driver for production

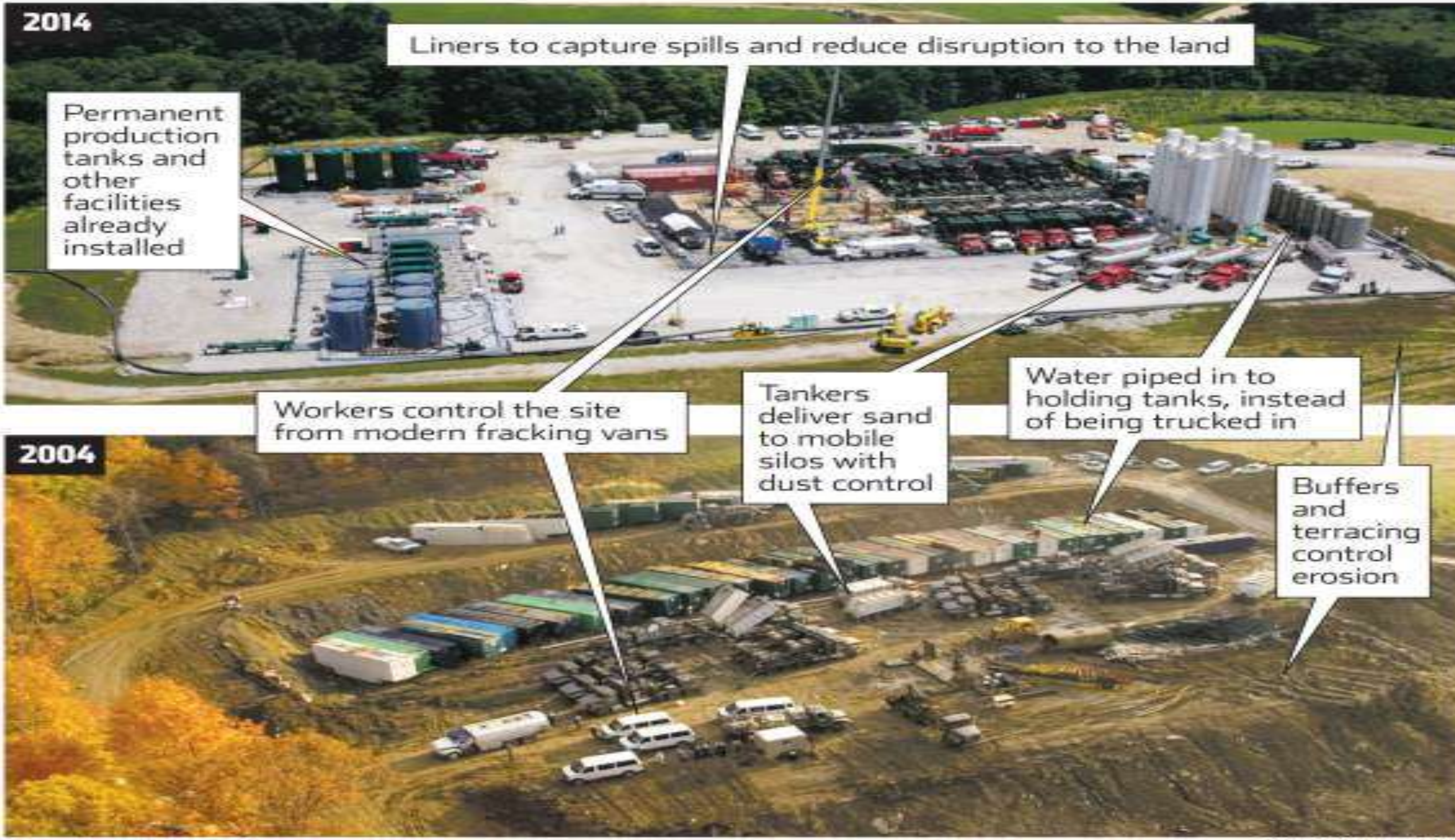
  -Pennsylvania operators recycling 85% of fluids, most other states less than 25% recycling

  -Reduced costs and environmental benefit of using less fresh water, less disposal, less trucking should lead to increased recycling of oil and gas produced fluids

Use of Best Environmental Practices

A decade of change

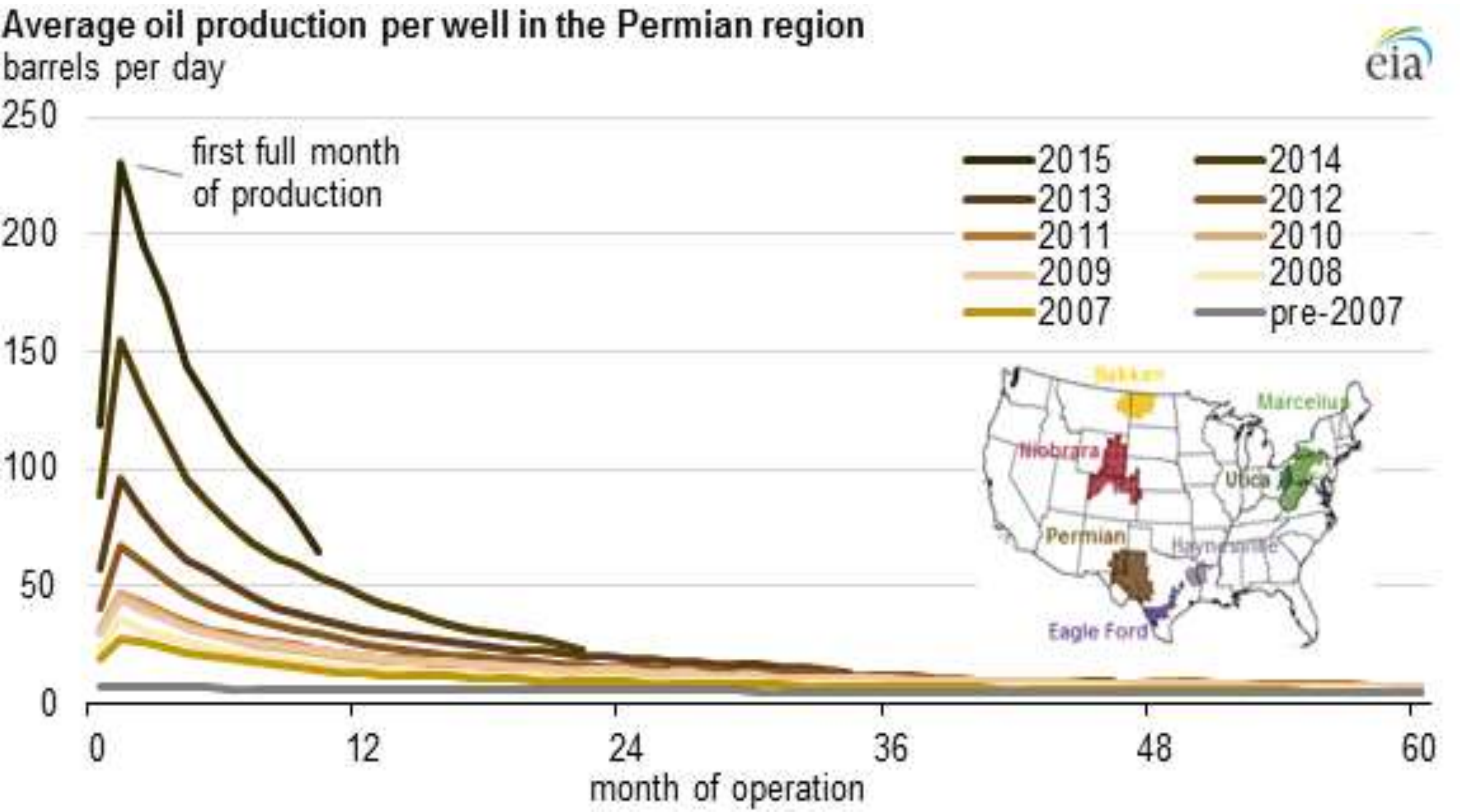
Vast improvement is illustrated in a modern gas well being hydraulically fractured and the Renz well that Range Resources Corp. completed in Washington County as the first producing well that tapped the Marcellus shale.



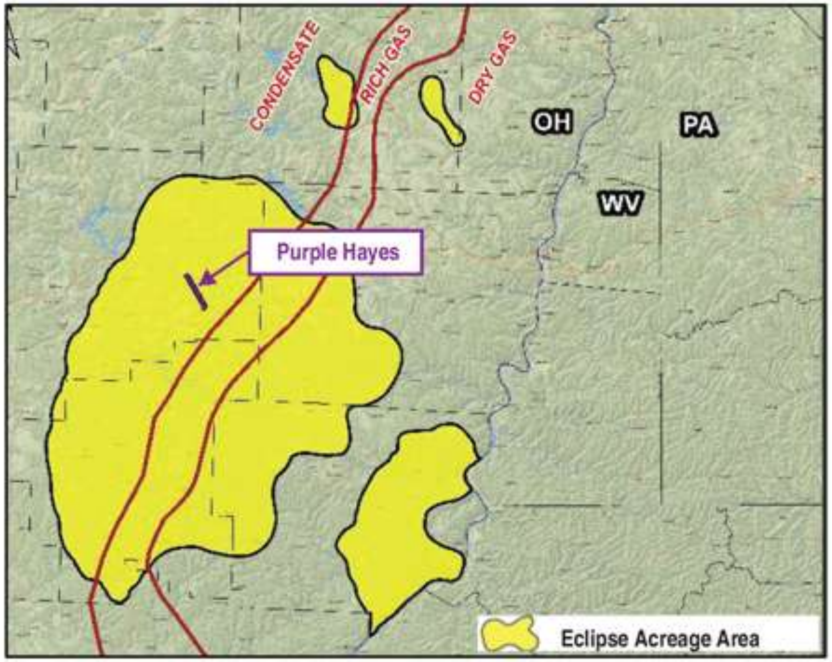
Source: *Range Resources Corp.*

TRIB TOTAL MEDIA

Drilling and Completion Advances = Improved Production Rates and EURs

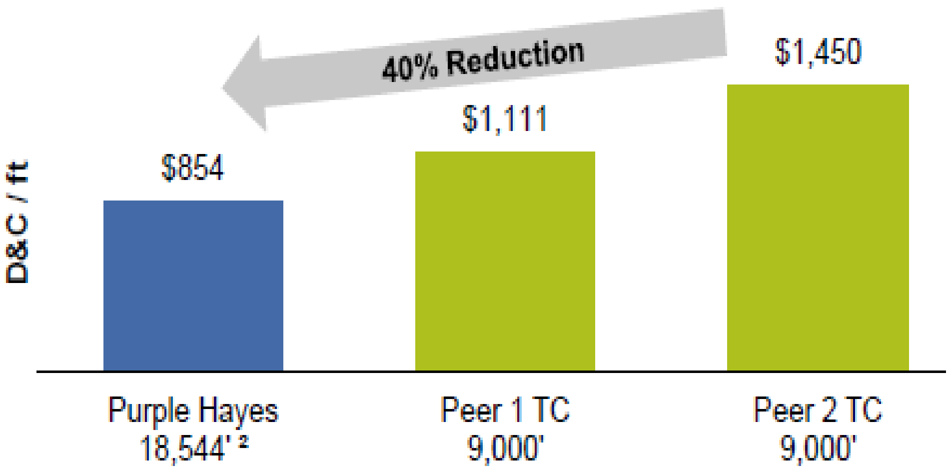


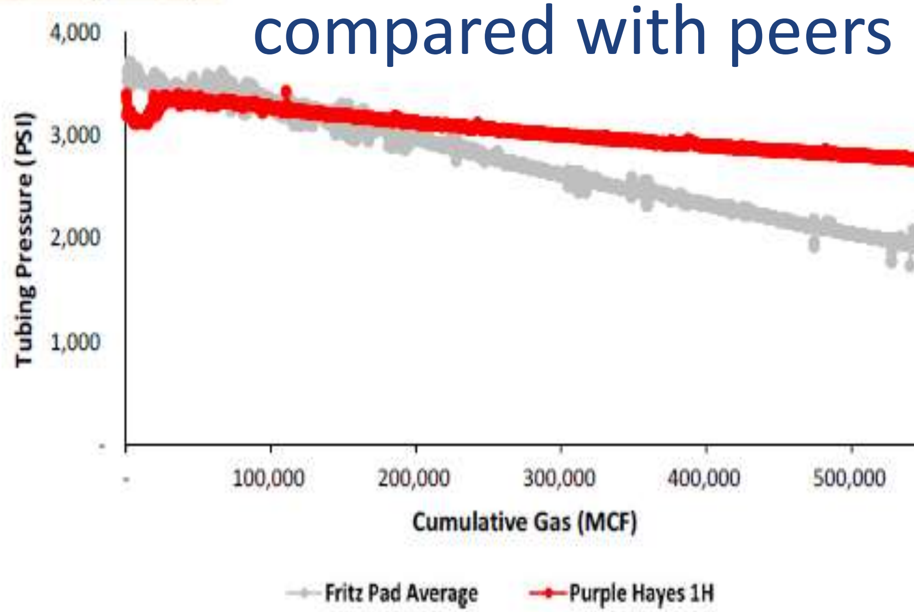
Longer Laterals=Lower Production Costs



Purple Hayes No. 1H
Guernsey County, Oh.
Longest lateral drilled onshore United States
Lateral length: 18,544 feet (drilled to TD in 17.6 days)
Total measured depth: 27,048 feet
Frac stages: 124 plug-and-perf at 150-foot spacing (completed in 23.5 days)
Total drilling and completion cost = $854/foot of lateral

Eclipse Resources' Purple Hayes Utica Shale well is the longest on-shore well in US with a lateral length of 18,544 feet, with lower costs per foot and increased production pressure compared with peers





Source: Eclipse Resources

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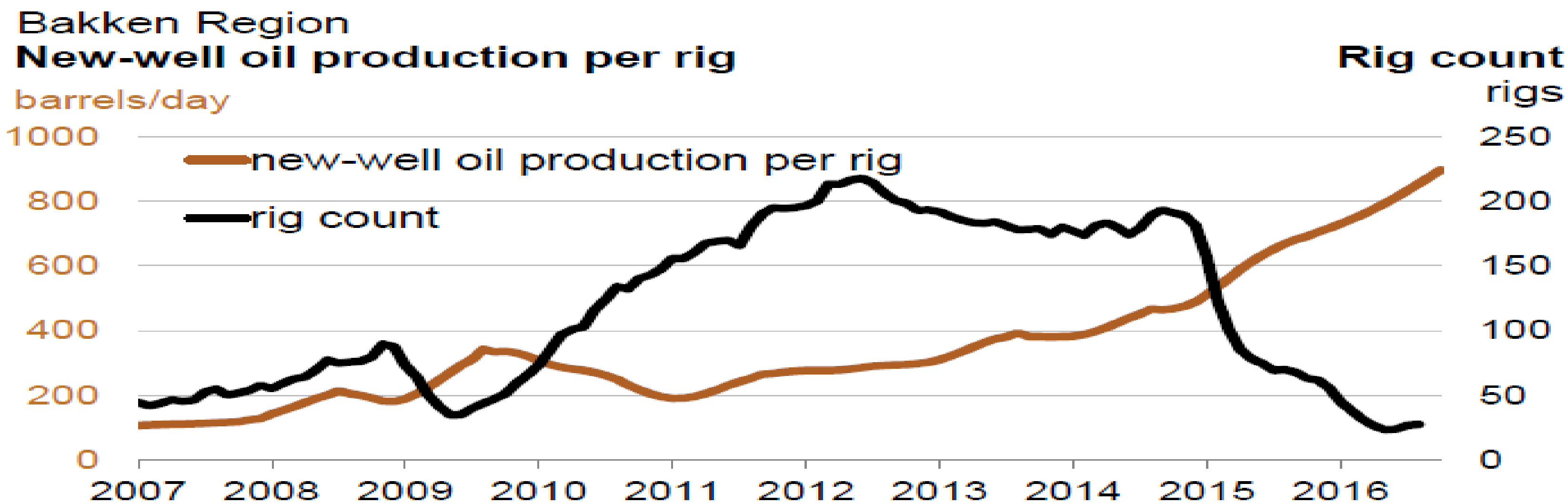
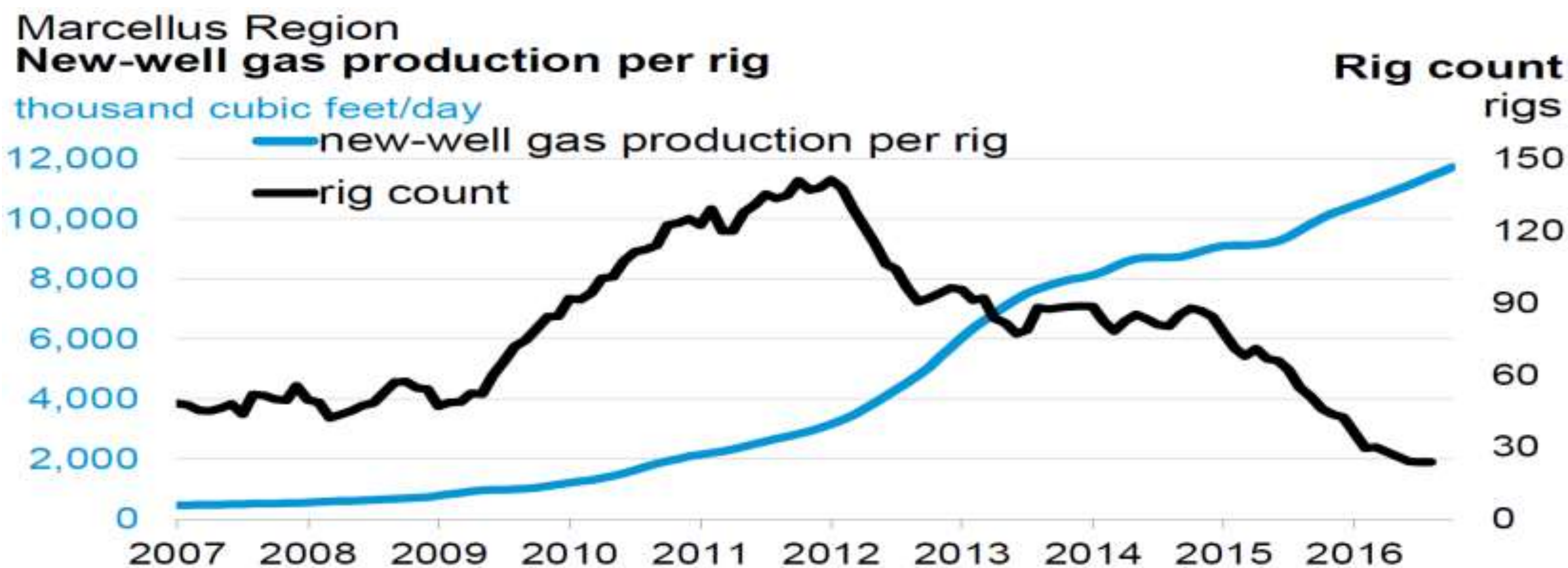
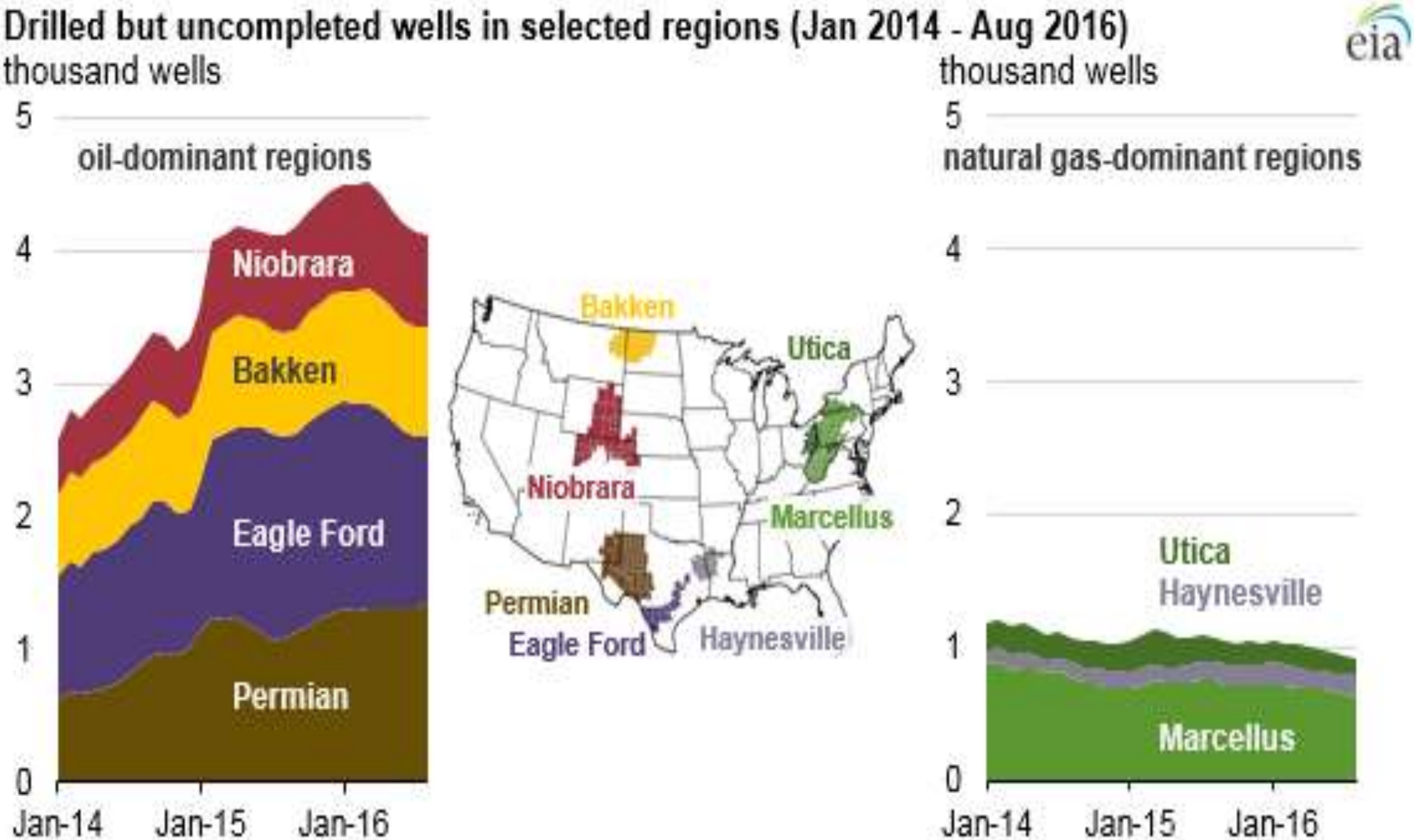
Fewer Rigs, but…..More Oil and Gas Per Rig



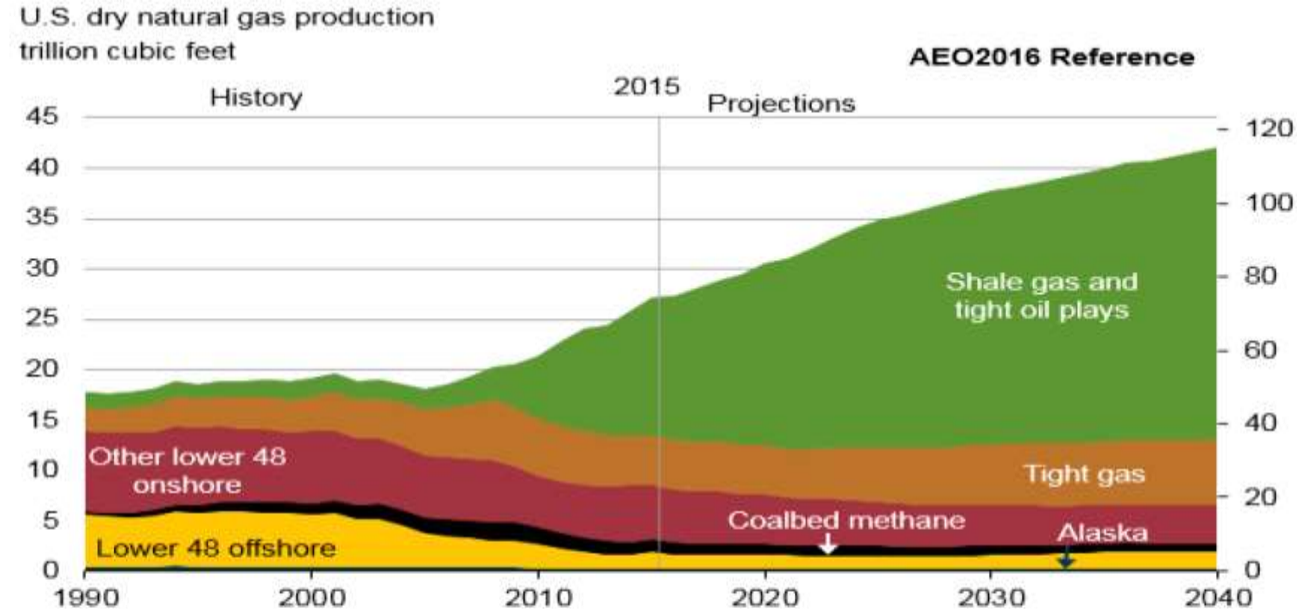


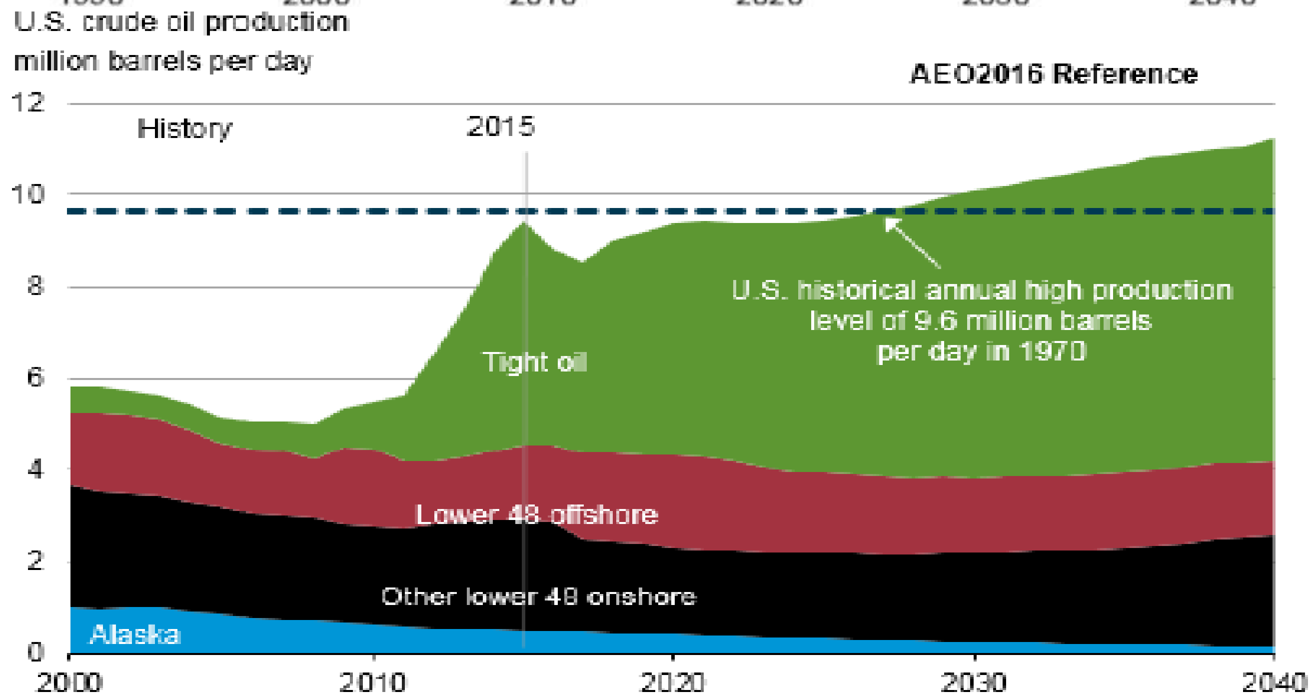
Shrinking Backlog of Uncompleted Wells



Oil and Gas Production Projections

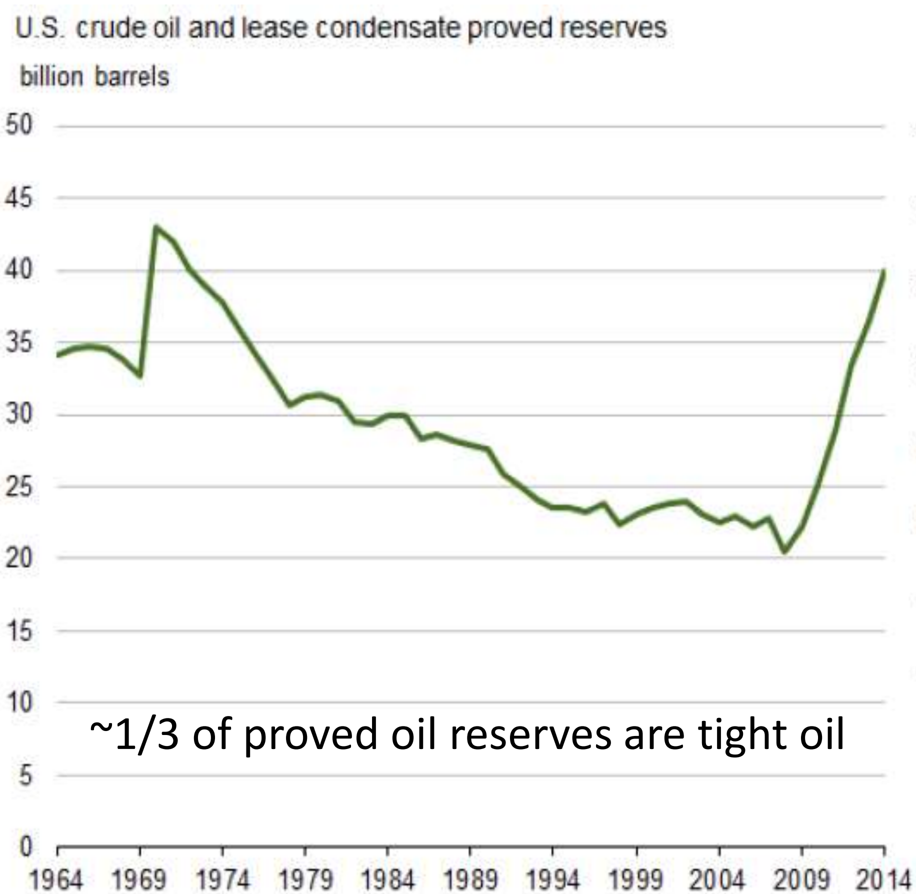
Best available projections show unconventional energy source production will continue to grow into the foreseeable future and comprise the majority of US oil and gas production, driven by advances in resource extraction technologies.

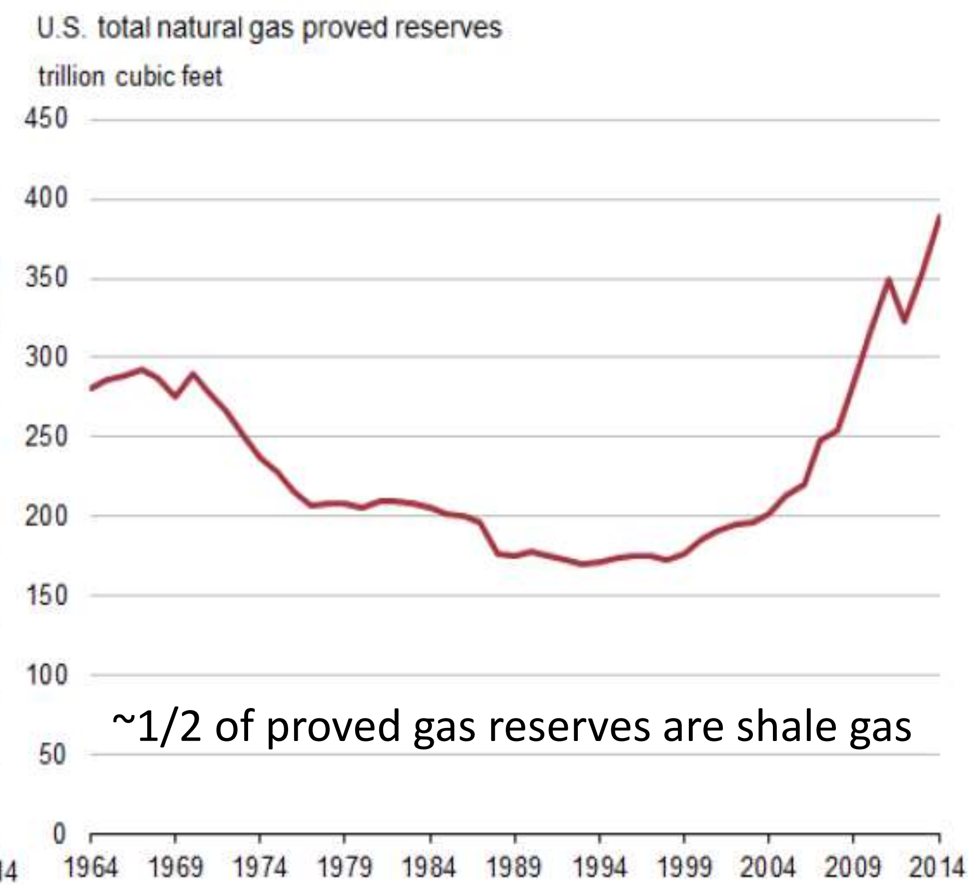




Source: EIA, Annual Energy Outlook 2016

Shale Energy Resources Adding to Proved Reserves



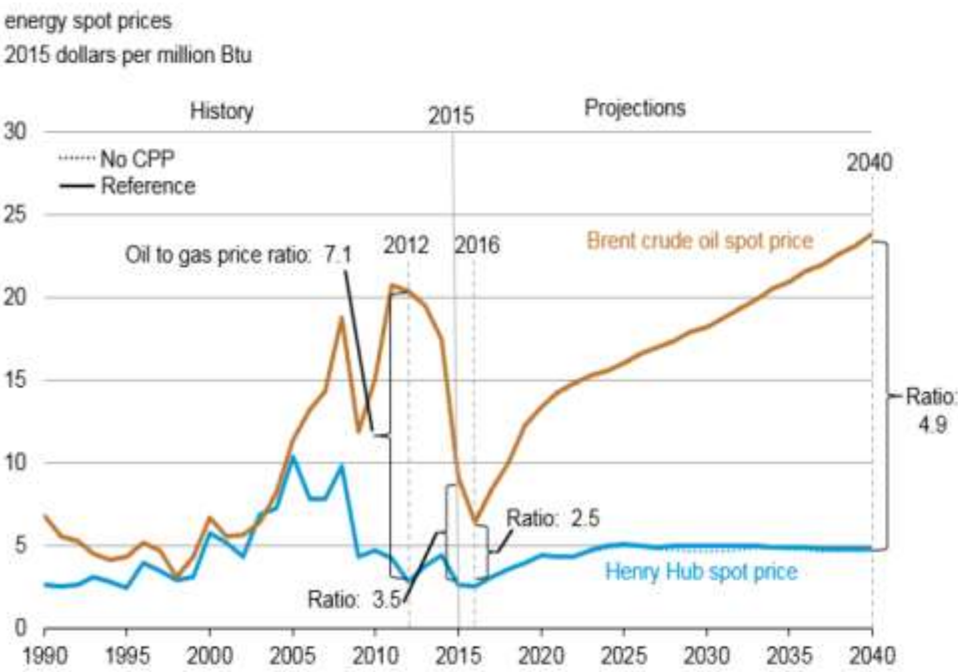


Sources: U.S. Energy Information Administration, Form EIA-23L, Annual Survey of Domestic Oil and Gas Reserves, 1977-2014, American Petroleum Institute, 1964-76

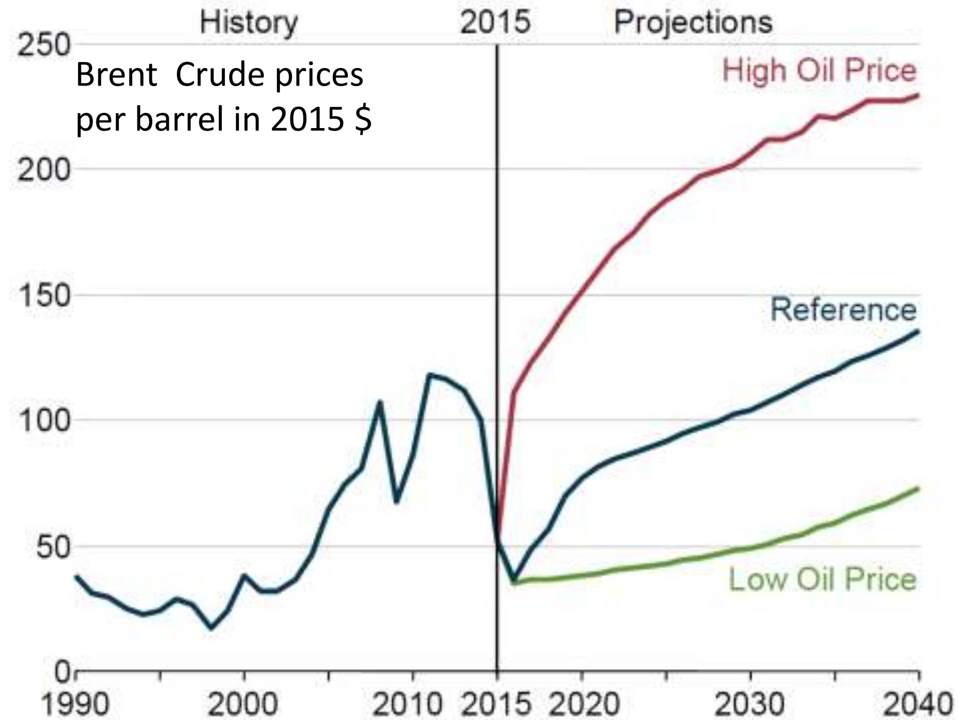
eia

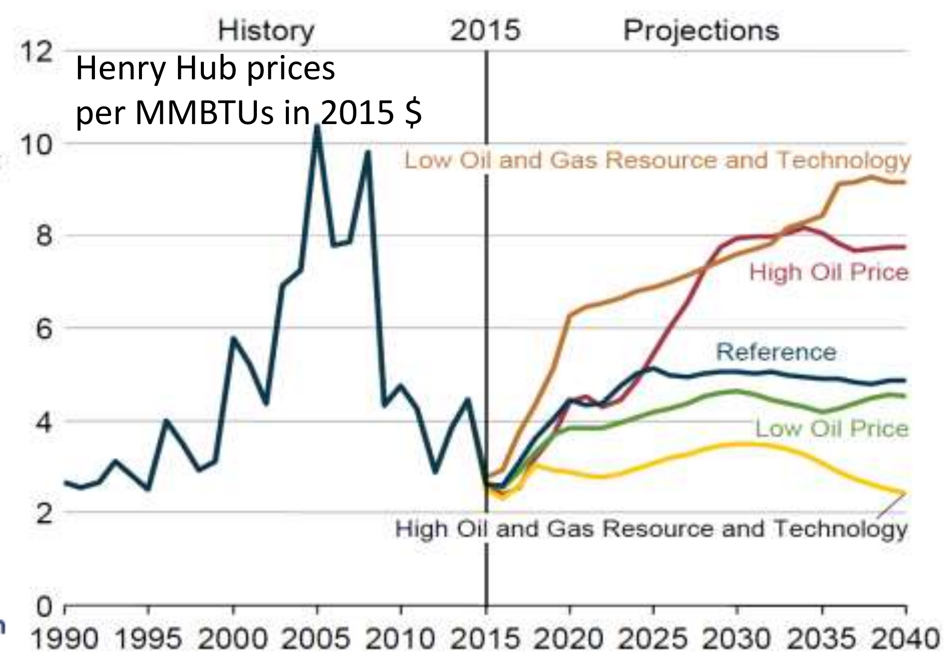
Future Oil and Gas Prices

The spread between oil and gas prices on an energy basis grows steadily thru 2040



Source: EIA, Annual Energy Outlook 2016





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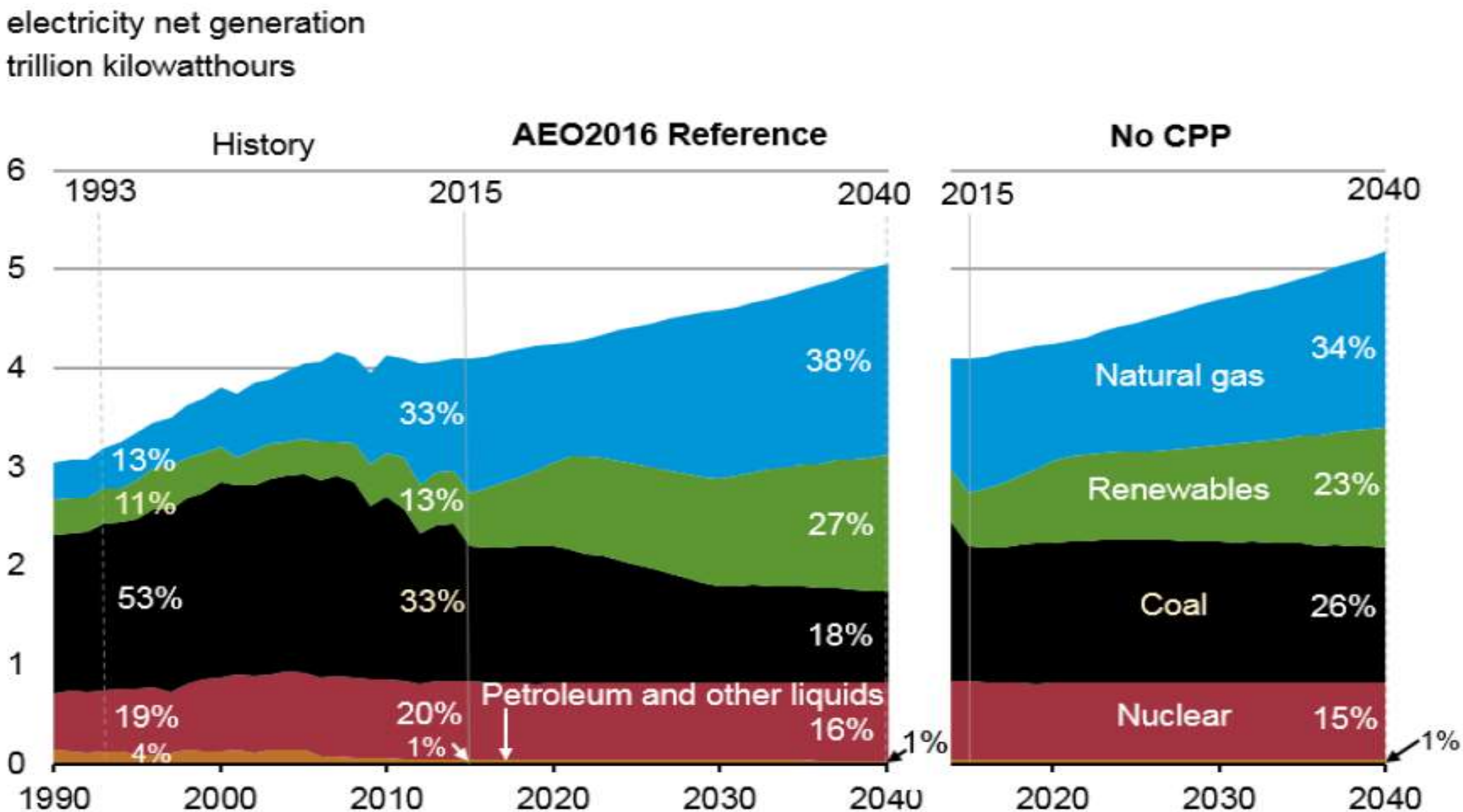
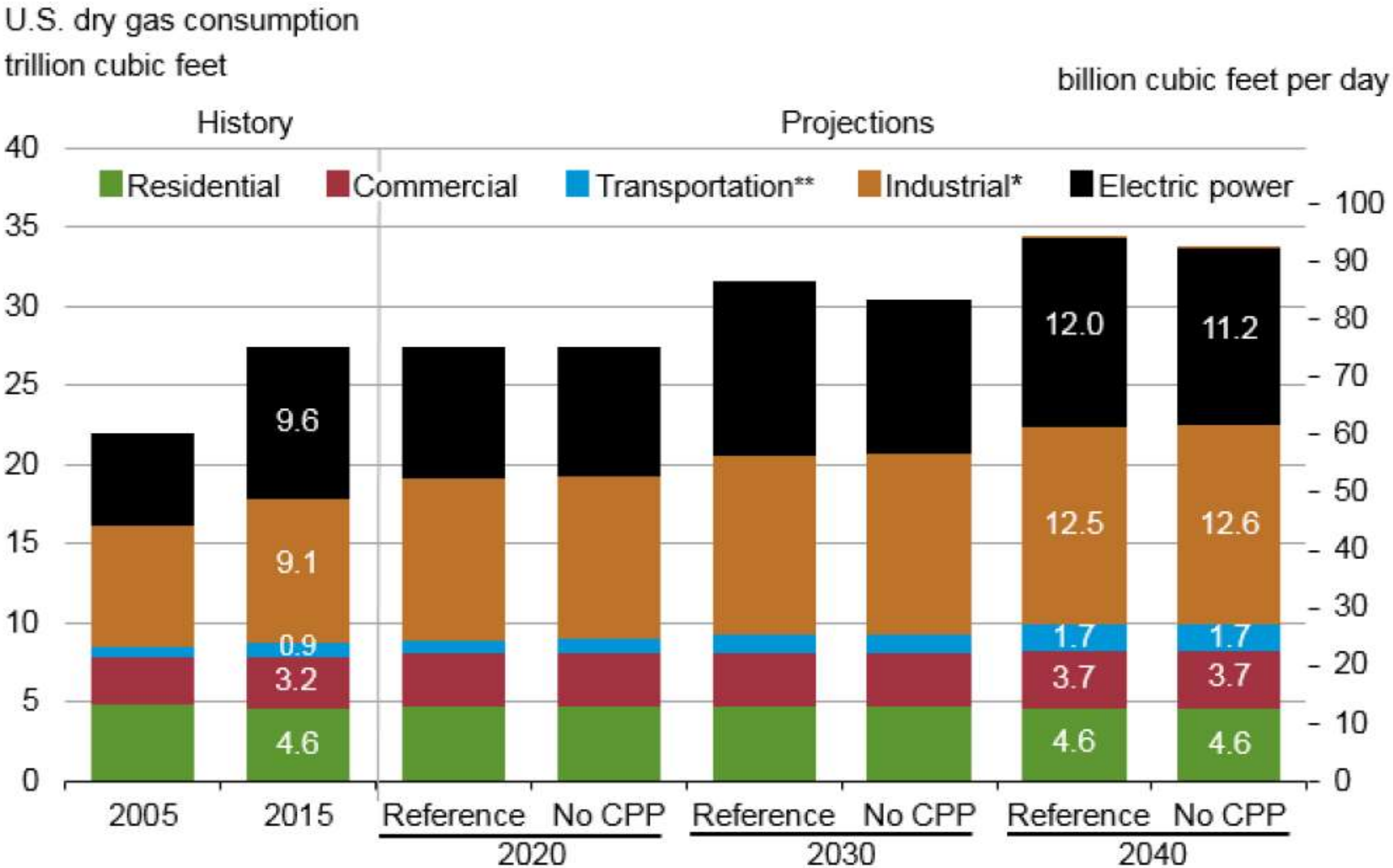
Natural Gas Utilization for Power Generation



Source: *EIA, Annual Energy Outlook 2016*

US Natural Gas Utilization



Source: EIA, Annual Energy Outlook 2016

**Includes combined heat-and-power and lease, plant, and export liquefaction fuel*
***Includes pipeline fuel*

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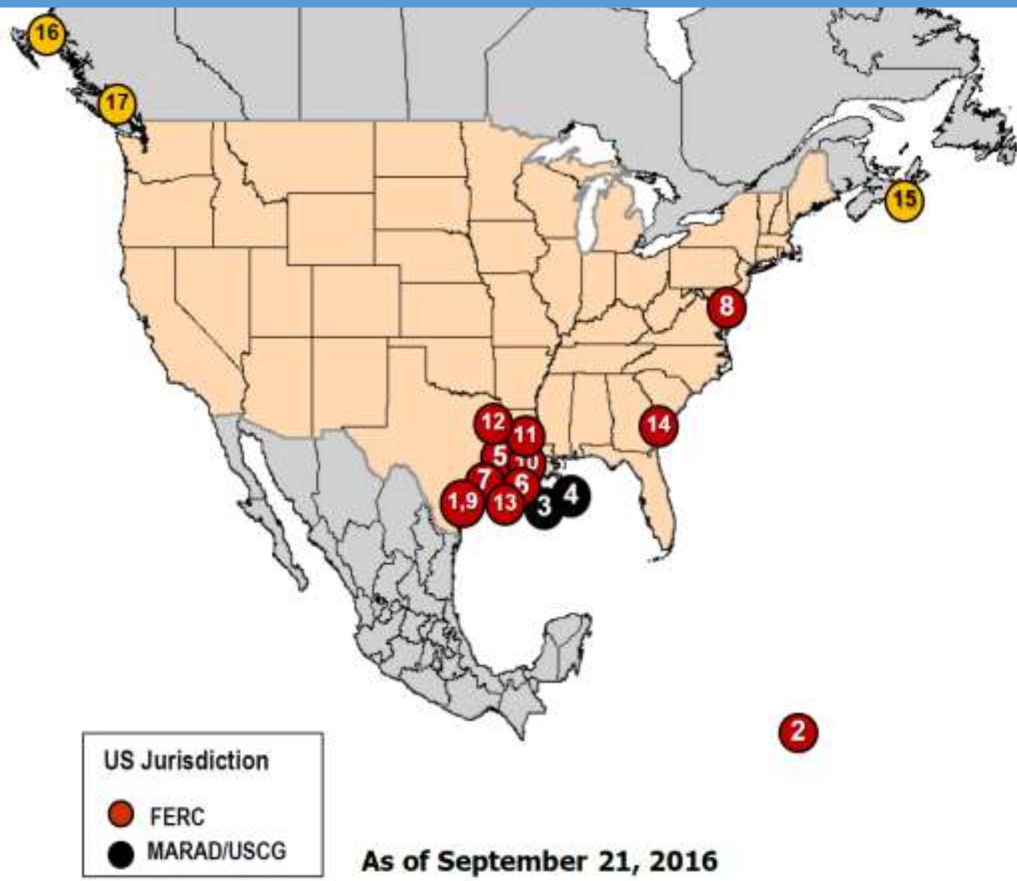
North American LNG Import/Export Terminals
Approved

9.22 BCFD of export capacity under construction, 5.04 BCFD export capacity approved, 0.9 BCFD export capacity operating (0.7 at Sabine, LA and 0.2 Kenai, AK)



As of September 21, 2016

Import Terminals

U.S.

APPROVED - UNDER CONSTRUCTION - FERC

1. **Corpus Christi, TX:** 0.4 Bcfd (Cheniere – Corpus Christi LNG) (CP12-507)

APPROVED – NOT UNDER CONSTRUCTION - FERC

2. **Salinas, PR:** 0.6 Bcfd (Aguirre Offshore GasPort, LLC) (CP13-193)

APPROVED - NOT UNDER CONSTRUCTION - MARAD/Coast Guard

3. **Gulf of Mexico:** 1.0 Bcfd (Main Pass McMoRan Exp.)
4. **Gulf of Mexico:** 1.4 Bcfd (TORP Technology-Bienville LNG)

Export Terminals

U.S.

APPROVED - UNDER CONSTRUCTION - FERC

5. **Sabine, LA:** 2.1 Bcfd (Cheniere/Sabine Pass LNG) (CP11-72 & CP14-12)
6. **Hackberry, LA:** 2.1 Bcfd (Sempra–Cameron LNG) (CP13-25)
7. **Freeport, TX:** 2.14 Bcfd (Freeport LNG Dev/Freeport LNG Expansion/FLNG Liquefaction) (CP12-509) (CP15-518)
8. **Cove Point, MD:** 0.82 Bcfd (Dominion–Cove Point LNG) (CP13-113)
9. **Corpus Christi, TX:** 2.14 Bcfd (Cheniere – Corpus Christi LNG) (CP12-507)
10. **Sabine Pass, LA:** 1.40 Bcfd (Sabine Pass Liquefaction) (CP13-552) ★

APPROVED – NOT UNDER CONSTRUCTION - FERC

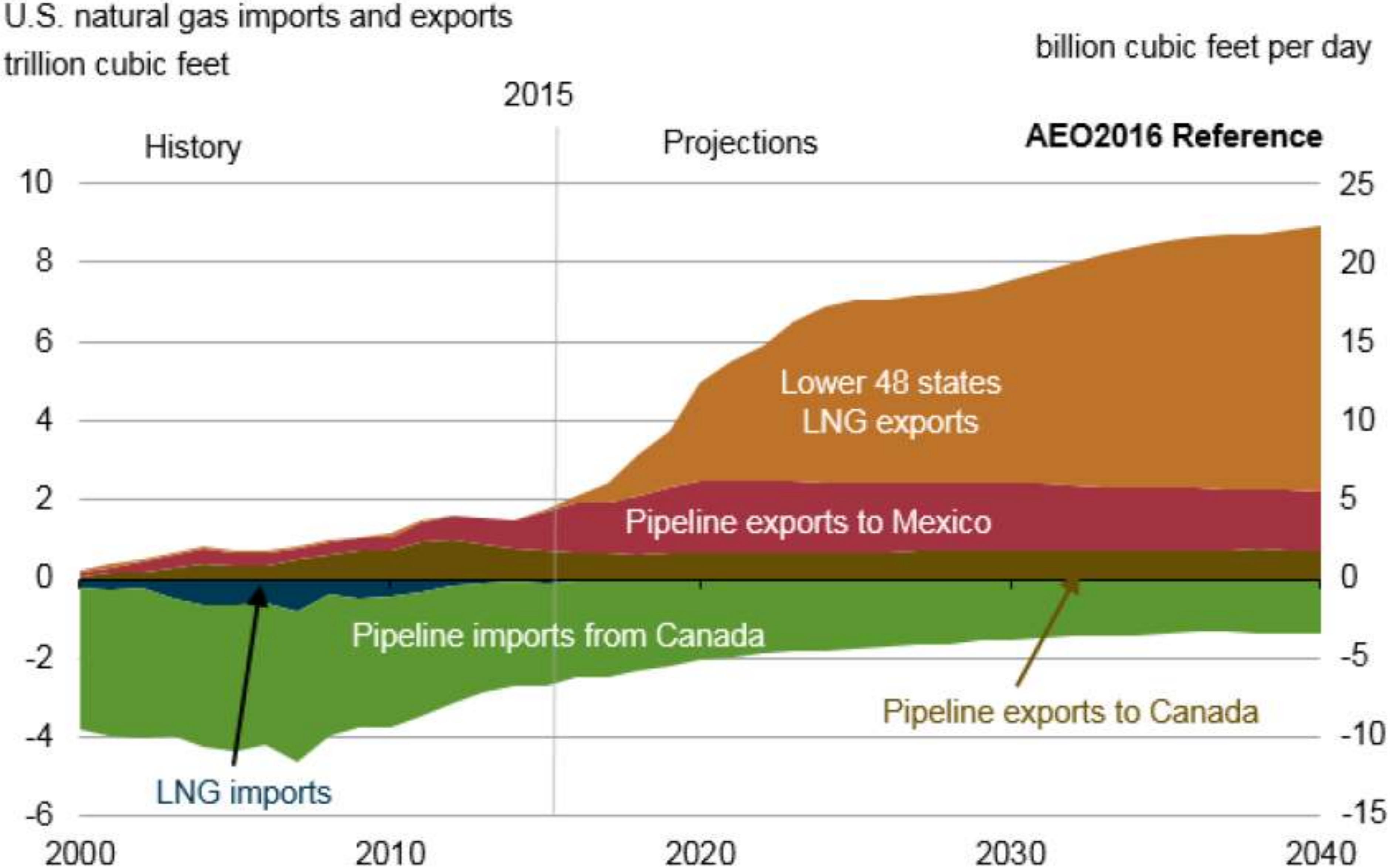
11. **Lake Charles, LA:** 2.2 Bcfd (Southern Union – Lake Charles LNG) (CP14-120)
12. **Lake Charles, LA:** 1.08 Bcfd (Magnolia LNG) (CP14-347)
13. **Hackberry, LA:** 1.41 Bcfd (Sempra - Cameron LNG) (CP15-560)
14. **Elba Island, GA:** 0.35 Bcfd (Southern LNG Company) (CP14-103)

Canada

APPROVED – NOT UNDER CONSTRUCTION

15. **Port Hawkesbury, NS:** 0.5 Bcfd (Bear Head LNG)
16. **Kitimat, BC:** 3.23 Bcfd (LNG Canada)
17. **Squamish, BC:** 0.29 Bcfd (Woodfibre LNG Ltd)

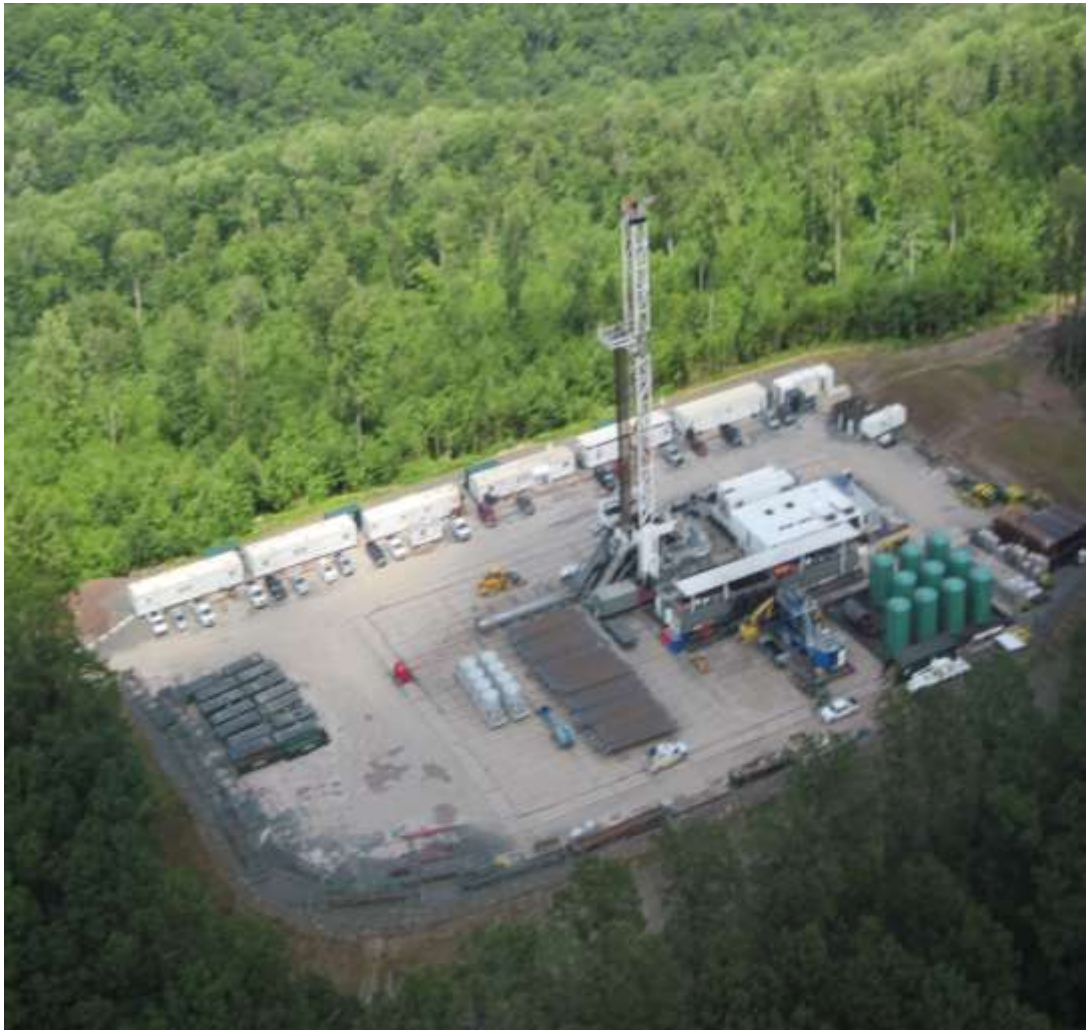
★ **Trains 5 & 6 with Train 5 under construction**



Source: EIA, Annual Energy Outlook 2016

What is Next in the Shale Energy Revolution?

- Technological innovation will continue to increase shale energy recovery efficiency and production with fewer wells and rigs at lower cost….producing more with less appears to be the mantra going forward!
- Moderate future commodity price growth should support continued shale gas production growth thru 2040 coupled with projected downstream increases in natural gas utilization for power generation, industrial uses, and LNG exports.
- Shale oil production growth continues thru 2040 with increasing prices and domestic demand primarily to offset decreases in oil imports



Questions??

Thank you!!

David Yoxtheimer, P.G.

Extension Associate

PSU MCOR

320 EES Building

University Park, PA 16802

814-865-1587 (office)

day122@psu.edu

www.marcellus.psu.edu