What is Next in the Shale Energy Revolution?

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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

Crude oil production
million barrels per day

- Rest of U.S.
- Federal Gulf of Mexico
- Permian region
- Eagle Ford region
- Bakken region

Marketed natural gas production
billion cubic feet per day

- Rest of U.S.
- Rest of U.S. shale
- Marcellus region

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.

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
Drilling and Completion Cost Reduction

Source: EIA, 2015
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.

Source: Seneca Resources
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.

2014

- Liners to capture spills and reduce disruption to the land
- Permanent production tanks and other facilities already installed
- Workers control the site from modern fracking vans
- Tankers deliver sand to mobile silos with dust control
- Water piped in to holding tanks, instead of being trucked in
- Buffers and terracing control erosion

2004

Source: Range Resources Corp.
Drilling and Completion Advances = Improved Production Rates and EURs

Average oil production per well in the Permian region (barrels per day)

- First full month of production

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Longer Laterals=Lower Production Costs

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

Bakken Region
New-well oil production per rig
barrels/day
1000
800
600
400
200
0
Rig count
rigs
250
200
150
100
50
0
new-well oil production per rig
rig count

Marcellus Region
New-well gas production per rig
thousand cubic feet/day
12,000
10,000
8,000
6,000
4,000
2,000
0
Rig count
rigs
150
120
90
60
30
0
new-well gas production per rig
rig count

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Shrinking Backlog of Uncompleted Wells

Drilled but uncompleted wells in selected regions (Jan 2014 - Aug 2016)

- Oil-dominant regions
  - Niobrara
  - Bakken
  - Eagle Ford
  - Permian

- Natural gas-dominant regions
  - Utica
  - Haynesville
  - Marcellus

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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

~1/3 of proved oil reserves are tight oil
~1/2 of proved gas reserves are shale gas

Future Oil and Gas Prices

The spread between oil and gas prices on an energy basis grows steadily thru 2040
US Natural Gas Utilization

U.S. dry gas consumption (trillion cubic feet)

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Projections (billion cubic feet per day)

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Source: EIA, Annual Energy Outlook 2016

*Includes combined heat-and-power and lease, plant, and export liquefaction fuel
**Includes pipeline fuel
North American LNG Import/Export Terminals
Approved

Import Terminals

U.S.

APPROVED - UNDER CONSTRUCTION - FERC
1. Corpus Christi, TX: 0.4 Bcf/d (Cheniere – Corpus Christi LNG) (CP12-507)

APPROVED – NOT UNDER CONSTRUCTION - FERC
2. Salinas, PR: 0.6 Bcf/d (Aguirre Offshore GasPort, LLC) (CP13-193)

APPROVED - NOT UNDER CONSTRUCTION - MARAD/Coast Guard
3. Gulf of Mexico: 1.0 Bcf/d (Main Pass McMoRan Exp.)
4. Gulf of Mexico: 1.4 Bcf/d (TORP Technology-Bienville LNG)

Export Terminals

U.S.

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

APPROVED – NOT UNDER CONSTRUCTION - FERC
11. Lake Charles, LA: 2.2 Bcf/d (Southern Union – Lake Charles LNG) (CP14-120)
12. Lake Charles, LA: 1.08 Bcf/d (Magnolia LNG) (CP14-347)
13. Hackberry, LA: 1.41 Bcf/d (Sempra - Cameron LNG) (CP15-560)
14. Elba Island, GA: 0.35 Bcf/d (Southern LNG Company) (CP14-103)

Canada

APPROVED – NOT UNDER CONSTRUCTION
15. Port Hawkesbury, NS: 0.5 Bcf/d (Bear Head LNG)
16. Kitimat, BC: 3.23 Bcf/d (LNG Canada)
17. Squamish, BC: 0.29 Bcf/d (Woodfibre LNG Ltd)

★ Trains 5 & 6 with Train 5 under construction

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)
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!!

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