Shale Gas: Myths and Realities

Long-term Sustainability and Implications for Future Energy Security

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Points to be covered:

- The SHALE REVOLUTION and CONVENTIONAL WISDOM

- SHALE GAS – A look at the fundamentals with examples from major U.S. plays

- IMPLICATIONS for long term energy sustainability
Conventional Wisdom

• The United States is on the verge of Energy Independence thanks to the “SHALE REVOLUTION”.

• Shale Gas production will continue to grow for the foreseeable future (2040 at least) and prices will remain low.

• The way is clear for U.S. LNG exports to monetize the shale gas bounty.

• Shale gas production, although temporarily in decline, can be turned around very quickly with a slight increase in prices. The sky is the limit when it comes to increasing production.

- **LNG Imports**
- **Canada Imports**
- **Shale Gas** (+93% 2012-2040)
- **Coalbed Methane**
- **Tight Gas**
- **Conventional**
- **Offshore**
- **Alaska**
- **Domestic Demand**

**Price**
- $2013 per MMbtu

- **Exports in 2040 (16% of Production)**
- **55% of 2040 Production**

**U.S. domestic consumption**

U.S. Shale Gas Production by Play, 2000-2040
EIA Reference Case AEO2015

Percent of 2014-2040 Production
- Marcellus = 32%
- Top 2 Plays = 49%
- Top 3 Plays = 61%

EIA AEO2015
Recovery 2014-2040 = 459 tcf

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(data from EIA AEO2014 and AEO2015)
U.S. Shale Gas Production by Play, 2000-2016

- **Rest of US**
- **Utica**
- **Woodford**
- **Marcellus**
- **Eagle Ford**
- **Antrim**
- **Bakken**
- **Fayetteville**
- **Barnett**
- **Haynesville**

**Current Production**
- Top Play = 37%
- Top 2 Plays = 48%
- Top 6 Plays = 78%

**5 Legacy Plays Collectively Peaked in August 2012 and are down 32% as of January 2016**

Peak October 2015

(data from EIA Natural Gas Weekly Update, March, 2016)
The Shale Play Life Cycle

• Discovery followed by leasing frenzy.

• Drilling boom follows to meet “held-by-production” lease requirements.

• Sweet spots identified, targeted and drilled off. *Companies always drill their best locations first.*

• Production rises rapidly and is maintained for cash-flow despite potentially uneconomic full-cycle costs.

• Sweet spots become saturated and well quality and field production decline.

• Plays like the Haynesville become middle aged after just five years.
SHALE PLAY LIFE CYCLE - Haynesville Gas Production and Number of Producing Wells, 2007-2015

- Peak November 2011
- Drilling Boom
- Leasing Boom
- Discovery
- Production Down 50%
- Decline

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(data from Drillinginfo, March, 2016)
Haynesville Play – Well Quality by Initial Gas Production

(map by John Van Hoesen based on data from Drillinginfo, August, 2014)
Haynesville Average Gas Well Decline Curve

First Year = 59%
Second Year = 54%
Third Year = 39%
Fourth Year = 23%

3-Year Decline = 89%

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(data from Drillinginfo, March, 2016)
Haynesville Field Decline – Gas Production from all Wells Drilled Prior to 2014

First Year Field Decline = 41%

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(data from Drillinginfo, March, 2016)
Haynesville Annual Gas Production Added per New Well, 2008-2015

Drilling Rate peaks @ 1100 wells/year
Production will fall to 3bcf/day with 200 wells/year @$9M/Well = $1.8 Billion/year

700 Wells per Year @ 7 bcf/day @$9M/Well = $6.3 Billion/year

Field Production Added per New Well
Wells Added in prior 12 months

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(data from Drillinginfo, February, 2014, three month trailing moving average)
Haynesville Well Productivity – Average Production Rate over First Six Months, 2011-2015

Peak well productivity 2014

Increase a result both of better technology and Sweet Spot focus

Down 4% from 2014 peak Sweet Spot exhaustion?

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(data from Drillinginfo, March, 2016)
Haynesville Gas Production Forecast in various Drilling Rate Scenarios through 2040

Peak 2011

Recovery to date 11.7 tcf
Recovery by 2040
30-50 tcf

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Haynesville Gas Production in Most Likely Rate Scenario through 2040 compared to EIA 2015 Projection

EIA AEO2015 excess
Most likely Production
EIA AEO2015
Most likely Wells

Peak 2011

EIA AEO2015
Recovery 2014-2040 = 79 tcf
An Extra 50 tcf (174%)

Recovery 2014-2040 = 29 tcf

© Hughes GSR Inc, 2015
(data from Drilling Deeper, 2014; EIA AEO2015 Reference Case Projection)
Distribution and elevation of Marcellus (feet)
Marcellus Gas Production and Number of Producing Wells, 2007-2015

Pennsylvania

Peak April 2015

WV

(data from Drillinginfo, March, 2016; PA 6-month trailing moving average; WV 3-month trailing moving average with 2015 estimated; EIA Weekly = natural gas weekly report March 13, 2016)
Marcellus Cumulative Gas Production by County December, 2015

Top 2 counties = 39% of production
Top 5 counties = 68% of production
Top 8 counties = 81% of production

(© Hughes GSR Inc, 2015)
(data from Drillinginfo; PA current to December, 2015; WV current to December, 2014)
### Marcellus Average Gas Well Decline Curves by County

#### 3-Year Decline
- **Susquehanna**: 81%
- **Bradford**: 72%
- **Lycoming**: 77%
- **Washington**: 81%
- **Next 4 counties**: 85%
- **Other counties**: 84%

![Graph showing decline curves for different counties](image-url)

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(data from Drillinginfo, March, 2016)
Estimated Ultimate Recoverable Gas per Well By County

- Susquehanna: 7.29 Billion Cubic Feet
  - Next 21 Years: 1017 Wells
  - First Four Years: 4.04 Billion Cubic Feet
- Bradford: 5.77 Billion Cubic Feet
  - Next 21 Years: 1046 Wells
  - First Four Years: 4.43 Billion Cubic Feet
- Lycoming: 4.43 Billion Cubic Feet
  - Next 21 Years: 745 Wells
  - First Four Years: 3.43 Billion Cubic Feet
- Washington: 3.43 Billion Cubic Feet
  - Next 21 Years: 1136 Wells
  - First Four Years: 2.60 Billion Cubic Feet
- Next 4 Counties: 2.60 Billion Cubic Feet
  - Next 21 Years: 4238 Wells
- Other Counties: 0.00 Billion Cubic Feet
  - Next 21 Years: 0 Wells
  - First Four Years: 0 Billion Cubic Feet

64% to 71% is Recovered in first 4 Years

(data from Drillinginfo, March, 2016)
Marcellus Average Well
First 12 Months of Production by County

Average First 12 Months of Production (Thousand cubic feet/day)

Susquehanna  Bradfod  Lycoming  Washington  Next 4 counties

Technology hits limit

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(data from Drillinginfo, March, 2016)
Marcellus Northeast Pennsylvania Sweetspot Well Footprint

(data from Drillinginfo, March, 2016)
Marcellus Northeast Pennsylvania Sweetspot Well Footprint

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(data from Drillinginfo, March, 2016)
Marcellus Gas Production Forecast by State in Most Likely Drilling Rate Scenario through 2040

Peak 2018

West Virginia Production
Pennsylvania Production
Most Likely Rate 1320 Wells/year declining to 920

Gas Production (Billion cubic feet per day)

Number of Producing Wells

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Recovery to date 17.3 tcf
Ultimate Recovery 129 tcf by 2040

(data from Drillinginfo, September, 2014)
Marcellus Gas Production in Most Likely Rate Scenario through 2040 compared to EIA AEO 2015

- EIA AEO2015 excess
- Most likely Production
- EIA AEO2015
- Most likely Wells

Peak 2018

EIA AEO2015
Recovery 2014-2040 = 147 tcf
An Extra 27 tcf (22%)

Recovery 2014-2040 = 120 tcf

© Hughes GSR Inc, 2015
(data from Drilling Deeper, 2014; EIA AEO2014 and EIA AEO2015)
Major Shale Play Well Quality in 2013
Average and Sweet Spots – First 12 month Production Rate

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(data from Drillinginfo, October, 2014)
Most Likely Drilling Rate Gas Production from Major Shale Plays through 2040 (88% of 2014 Production)

Gas Production (Billion cubic feet/per day)

Marcellus
Haynesville
Eagle Ford
Bakken
Woodford
Fayetteville
Barnett
Most likely Wells

Recovery to date 59 tcf
Remaining 232 tcf 2015-2040

Peak 2017

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(data from Drillinginfo, September, 2014, 32)
Most Likely Gas Production from Major Shale Plays through 2040 Compared to EIA AEO 2015 Projection

- EIA 2015 Additional
- Marcellus
- Haynesville
- Eagle Ford
- Bakken
- Woodford
- Fayetteville
- Barnett

Recovery to date 59 tcf Remaining 232 tcf 2015-2040

Peak 2017

EIA 2015 Additional 125 tcf 2015-2040 or 54% more

2040 EIA Production 170% Higher

© Hughes GSR Inc, 2016 (data from Drillinginfo, September, 2014; EIA AEO2015)
Most Likely Gas Production from Major Shale Plays through 2040 with EIA AEO 2015 Additions

- EIA 2015 Other Plays
- EIA 2015 Additional
- Marcellus
- Haynesville
- Eagle Ford
- Bakken
- Woodford
- Fayetteville
- Barnett

Recovery to date 59 tcf Remaining 232 tcf 2015-2040

EIA 2015 Other plays 89 tcf 2015-2040
EIA 2015 Additional From Major Plays 125 tcf 2015-2040 or 54% more

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(data from Drillinginfo, September, 2014; EIA AEO2015)
Summary and Implications

- Shale has been a game-changer in the short-term, but projections of long-term sustainability at low prices are highly questionable.

- High quality shale plays are not ubiquitous – and plays are not uniform. Sweet spots are exploited early in the development process. The best parts of major plays are being drilled NOW.

- High well decline rates require a drilling treadmill and high capital inputs to sustain production and offset field declines, along with associated environmental impacts.

- Assuming long term sustainability of production at low prices is folly for energy policy. The shale revolution is a temporary windfall and should be viewed as such.
Summary and Implications

- U.S. “Energy Independence” with the forecast energy trajectory is highly unlikely, barring a radical reduction in consumption and a major ramp up of renewable energy.

- A sustainable energy future requires a vision beyond the next couple of quarters or the next election. In the absence of a coherent plan, investments assuming cheap oil and gas in the long term are very likely to end badly.