The Shale Revolution in North America: Myths and Realities

Beyond the Hype: Economics of Shale Gas in Europe
EU Parliament
Brussels, Belgium
May 14, 2013

J. David Hughes
Post Carbon Institute
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 below $4.50/mcf for the next 10 years and below $6.00/mcf for the next 20 years.

- Shale Gas can replace very substantial amounts of oil for transport and coal for electricity generation.

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

- Tight Oil will allow U.S. production to exceed that of Saudi Arabia and U.S. imports will shrink to zero.

- The Shale “REVOLUTION” will provide Europe with a growing supply cheap gas for the foreseeable future.

© Hughes GSR Inc, 2012
U.S. Natural Gas Supply Projection by Source, 2010-2040, EIA Reference Case 2013

Trillion Cubic Feet per Year

Year

2010 2015 2020 2025 2030 2035 2040

LNG Imports Canada Imports Shale Gas
Alaska Coalbed Methane Tight Gas
Associated Conventional Offshore

55% increase in production by 2040

U.S. Domestic consumption

Exports

50% of 2040 Production

EIA Projections of Gas Price and U.S. Production Compared to History, 1995-2040

- **Russian Gas Price**
- **Indonesia LNG Gas Price in Japan**
- **U.S. Henry Hub Gas Price**
- **EIA Forecast U.S. Gas Price ($2011)**
- **Actual U.S. Gas Production**
- **EIA Forecast U.S. Gas Production**

(Data from EIA Annual Energy Outlook 2013, EIA, 2012; International Monetary Fund)
U.S. Gas Production and Imports, 1998-2012

Trillion Cubic Feet per Year

- Net LNG Imports
- Net Canadian Imports
- Dry Gas Production

Year


© Hughes GSR Inc, 2013
(data from EIA current to August, 2012)
Barnett Shale Production by Well Type, 2000-2012, Illustrating Impact of Horizontal Drilling Technology

93% of Production is from Horizontal Wells

© Hughes GSR Inc, 2012

(data from DIdesktop, June, 2012, fitted with 5 month centered moving average including data up to March, 2012)
U.S. Rig Count by Type, 2000-2013

Horizontal Rigs now Dominate

- Vertical
- Directional
- Horizontal

© Hughes GSR Inc, 2013
(data from Baker-Hughes, March, 2013)
Breakeven Gas Price by Shale Play for a 10% Rate of Return

(data from Jacoby et al., Economics of Energy and Environmental Policy, vol. 1, no.1, 2012)

© Hughes GSR Inc, 2012
U.S. Dry Gas Production, 2010-2013

U.S. production plateau September 2012-February 2013

(data from EIA Natural Gas Monthly, May, 2013)
Shale Gas Production by Play, 2000-2012

Billion Cubic Feet per Day

- Other
- Austin Chalk
- Bone Spring
- Bossier
- Antrim
- Niobrara
- Bakken
- Woodford
- Eagle Ford
- Fayetteville
- Marcellus
- Barnett
- Haynesville

40% of U.S. production

Year


(data from DIdesktop, September, 2012, fitted with 3 month centered moving average including data up to June, 2012)
Shale Gas Production by Play, May 2011 – May 2012

Billion Cubic Feet per Day

Other
Austin Chalk
Bone Spring
Bossier
Antrim
Niobrara
Bakken
Woodford
Eagle Ford
Fayetteville
Marcellus
Barnett
Haynesville

May-11 Jul-11 Sep-11 Nov-11 Jan-12 Mar-12 May-12

Year

(data from DI Desktop, HPDI, September, 2012)
Shale Gas Production by Play

Top 3 Plays = 66% of Total
Top 6 Plays = 88% of Total

(data from DI Desktop, September, 2012, for production in most cases through May-June, 2012)
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.

- Gas production rises rapidly and is maintained for cash-flow despite 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.

© Hughes GSR Inc, 2012
Haynesville Well Quality - Top 20% with Highest One Month Production of >10989 mcf/day in black
Haynesville Type Gas Well Decline Curve

Yearly Declines:
- First year = 66%
- Second year = 49%
- Third year = 41%
- Fourth year = 49%

(data from DrillingInfo/HPDI, March, 2013)
Overall Field Decline for Haynesville Gas Production based on Production Decline from pre-2012 Wells

Overall Field Decline = 47%

(data from DrillingInfo/HPDI, March, 2013)
Haynesville Average Production per Well

- **Average Production per Well (Thousand cubic feet per day)**
- **Number of Wells**

(data from DrillingInfo/HPDI, March, 2013)
Haynesville Annual Production Added per New Well

Need 680 wells per year to keep production flat

© Hughes GSR Inc, 2013
(data from DrillingInfo/HPDI, March, 2013)
Haynesville Well Quality

Highest One Month Gas Production from Individual Wells

Median = 7954 mcf/day
Mean = 8201 mcf/day

© Hughes GSR Inc, 2012
(data from DI Desktop, HPDI, September, 2012)
Haynesville Operating Wells with Sweet Spot (Red)

Sweet Spot
30 by 18 miles
<20% of Field

© Hughes GSR Inc, 2013
Haynesville Production from Sweet Spot vs Non-Sweet Spot Areas

Sweet Spot comprises 29% of the total wells and produces 39% of the gas.

Non-Sweet Spot = >80% of area

Sweet Spot = <20% of area

© Hughes GSR Inc, 2013
Haynesville Type Gas Well Decline Curves
Sweet Spot vs Areas outside Sweet Spot

- **Sweet Spot**
  - First year = 64%
  - Second year = 40%
  - Third year = 32%
  - Fourth year = 40%

- **Outside Sweet Spot**
  - First year = 68%
  - Second year = 54%
  - Third year = 50%
  - Fourth year = 32%

Sweet Spot EUR = 5.6 bcf
Outside Sweet Spot EUR = 2.9 bcf

(data from DrillingInfo/HPDI, May, 2013)
Overall Field Decline for Haynesville Gas Production based on Production Decline from pre-2012 Wells

- Production from pre-2012 Sweet Spot Wells
- Production from pre-2012 Non-Sweet Spot Wells

Sweet Spot Field Decline = 41%
Non-Sweet Spot Field Decline = 49%

(data from DrillingInfo/HPDI, March, 2013)
Haynesville Average Production per Well Comparing Sweet Spot to Non-Sweet Spot Wells

- **Average Production per Sweet Spot Well**
- **Average Production per Non-Sweet Spot Well**
- **Number of Sweet Spot Wells**
- **Number of Non-Sweet Spot Wells**

*Data from DrillingInfo/HPDI, May, 2013*
Barnett Well Quality - Top 20% with Highest One Month Production of >2436 mcf/day in black
Barnett Well Quality - Top 20% with Highest One Month Production of >2436 mcf/day in black
Barnett Type Gas Well Decline Curve

Yearly Declines:
- First year = 58%
- Second year = 33%
- Third year = 26%
- Fourth year = 20%

(data from DrillingInfo/HPDI, March, 2013)
Overall Field Decline for Barnett Gas Production based on Production Decline from pre-2012 Wells

Overall Field Decline = 28%

© Hughes GSR Inc, 2013
(data from DrillingInfo/HPDI, March, 2013)
Barnett Average Production per Well

Average Production per Well (Thousand cubic feet per day)

Year

© Hughes GSR Inc, 2013
(data from DrillingInfo/HPDI, March, 2013)
University of Texas Barnett Study Heralded as a Good News Story of Long Term Growth by Wall Street Journal (Feb 2013)

Base Case Production by Year

- Peak 2012
- 60% Decline by 2030

Source: Bureau of Economic Geology/Univ. of Texas at Austin QAE1590
Marcellus Well Quality - Top 20% with Highest One Month Production of >3603 mcf/day in black
Pennsylvania Marcellus Daily Well Production by Well Type

- Horizontal Average Production
- Vertical Average Production
- Total Average Production

Average Daily Production per Well (Thousand Cubic Feet per Day)

© Hughes GSR Inc, 2013
Pennsylvania Marcellus Production By County

Top 2 counties = 46% of production
Top 4 counties = 68% of production
Top 6 counties = 85% of production
Pennsylvania Marcellus Production and Number of Horizontal Wells by County

Production

- Remaining 27 counties (15%)
- Washington (9%)
- Tioga (9%)
- Greene (10%)
- Lycoming (12%)
- Susquehanna (22%)
- Bradford (24%)

Number of Wells

- Remaining 27 counties (20%)
- Washington (15%)
- Tioga (14%)
- Greene (9%)
- Lycoming (10%)
- Susquehanna (12%)
- Bradford (20%)

Bradford and Susquehanna counties produce 46% of the gas with 32% of the wells.

© Hughes GSR Inc, 2013
Type Decline Curves for Marcellus Horizontal Wells by County

Gas Production (Mcf per Day)

Months on Production

Bradford (24%)
Susquehanna (22%)
Lycoming (12%)
Greene (10%)
Tioga (10%)
Washington (9%)
Remaining 27 Counties (15%)

© Hughes GSR Inc, 2013
Estimated Ultimate Recovery for Pennsylvania Marcellus Horizontal Wells By County

62%-77% produced in first 3 years
EIA EUR estimate of 1.56 bcf underestimates best Counties

© Hughes GSR Inc, 2013
Top Tier Counties (Red=Horizontal; Black=Vertical)
Horizontal Well Quality Trends – Top Five Shale Gas Plays

Marcellus - Youth
Fayetteville – Early Middle Age
Barnett – Middle Age
Haynesville – Late Middle Age
Woodford – Early Old Age

Average Initial Productivity per Well Indexed to 2010

© Hughes GSR Inc, 2013
(data from DrillingInfo/HPDI, March, 2013)
## Prognosis for Future Production based on Latest Rig Count

<table>
<thead>
<tr>
<th>Field</th>
<th>Rank</th>
<th>Number of Wells needed annually to offset decline</th>
<th>Wells Added for most recent Year</th>
<th>October 2012 Rig Count</th>
<th>Prognosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haynesville</td>
<td>1</td>
<td>774</td>
<td>810</td>
<td>20</td>
<td>Decline</td>
</tr>
<tr>
<td>Barnett</td>
<td>2</td>
<td>1507</td>
<td>1112</td>
<td>42</td>
<td>Decline</td>
</tr>
<tr>
<td>Marcellus</td>
<td>3</td>
<td>561</td>
<td>1244</td>
<td>110</td>
<td>Growth</td>
</tr>
<tr>
<td>Fayetteville</td>
<td>4</td>
<td>707</td>
<td>679</td>
<td>15</td>
<td>Decline</td>
</tr>
<tr>
<td>Eagle Ford</td>
<td>5</td>
<td>945</td>
<td>1983</td>
<td>274</td>
<td>Growth</td>
</tr>
<tr>
<td>Woodford</td>
<td>6</td>
<td>222</td>
<td>170</td>
<td>61</td>
<td>Decline</td>
</tr>
<tr>
<td>Granite Wash</td>
<td>7</td>
<td>239</td>
<td>205</td>
<td>N/A</td>
<td>Decline</td>
</tr>
<tr>
<td>Bakken</td>
<td>8</td>
<td>699</td>
<td>1500</td>
<td>186</td>
<td>Growth</td>
</tr>
<tr>
<td>Niobrara</td>
<td>9</td>
<td>1111</td>
<td>1178</td>
<td>~60</td>
<td>Flat</td>
</tr>
</tbody>
</table>

© Hughes GSR Inc, 2012
## Annual Capex Required to Offset Overall Annual Decline by Shale Play

<table>
<thead>
<tr>
<th>Field</th>
<th>Rank</th>
<th>Number of Wells needed annually to offset decline</th>
<th>Approximate Well Cost (million $US)</th>
<th>Annual Well Cost to Offset Decline (million $US)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haynesville</td>
<td>1</td>
<td>774</td>
<td>9.0</td>
<td>6966</td>
</tr>
<tr>
<td>Barnett</td>
<td>2</td>
<td>1507</td>
<td>3.5</td>
<td>5275</td>
</tr>
<tr>
<td>Marcellus</td>
<td>3</td>
<td>561</td>
<td>4.5</td>
<td>2525</td>
</tr>
<tr>
<td>Fayetteville</td>
<td>4</td>
<td>707</td>
<td>2.8</td>
<td>1980</td>
</tr>
<tr>
<td>Eagle Ford</td>
<td>5</td>
<td>945</td>
<td>8.0</td>
<td>7558</td>
</tr>
<tr>
<td>Woodford</td>
<td>6</td>
<td>222</td>
<td>8.0</td>
<td>1776</td>
</tr>
<tr>
<td>Granite Wash</td>
<td>7</td>
<td>239</td>
<td>6.0</td>
<td>1434</td>
</tr>
<tr>
<td>Bakken</td>
<td>8</td>
<td>699</td>
<td>10.0</td>
<td>6990</td>
</tr>
<tr>
<td>Niobrara</td>
<td>9</td>
<td>1111</td>
<td>4.0</td>
<td>4444</td>
</tr>
<tr>
<td>Antrim</td>
<td>10</td>
<td>~400</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Bossier</td>
<td>11</td>
<td>21</td>
<td>9.0</td>
<td>189</td>
</tr>
<tr>
<td>Bone Spring</td>
<td>12</td>
<td>206</td>
<td>3.7</td>
<td>762</td>
</tr>
<tr>
<td>Austin Chalk</td>
<td>13</td>
<td>127</td>
<td>7.0</td>
<td>889</td>
</tr>
<tr>
<td>Permian Delaware Midland</td>
<td>14</td>
<td>122</td>
<td>6.9</td>
<td>842</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>7641</strong></td>
<td></td>
<td><strong>41829</strong></td>
</tr>
</tbody>
</table>

© Hughes GSR Inc, 2012

(Well cost data from various sources and is approximate)
"We are all losing our shirts today." Rex Tillerson [CEO of Exxon Mobil] said "We're making no money. It's all in the red."
(Wall Street Journal, June, 2012)

2012 Impairment Charges on U.S. Shale Assets

- Chesapeake - $2.02 Billion
- BP - $2.11 Billion
- BHP - $2.84 Billion
- BG Group - $1.3 Billion
And there is no such thing as a **FREE LUNCH**

There has been a great deal of pushback by many in the general public and in State and National governments to environmental issues surrounding hydraulic fracturing.
- High levels of water consumption
- Methane contamination of groundwater
- Disposal of produced fracture fluid potentially contaminating groundwater and inducing earthquakes
- Industrial footprint – truck traffic, air emissions etc.
- Full cycle greenhouse gas emissions which may be worse than coal
The Shale “REVOLUTION”

• Over-hyped in terms of long term supply especially at low forecast prices.

• High quality shale plays are not ubiquitous - 88% of shale gas production comes from 6 of 30 plays; 81% of tight oil production comes from 2 of 21 plays.

• High field decline rates require a drilling treadmill to maintain production – 30-50% of production must be replaced each year with more drilling.

• The drilling treadmill will accelerate as sweet spots are drilled off and well quality declines as drilling moves into more marginal areas.

• Collateral environmental impacts associated with fracking have already, and will continue to create public opposition to unfettered access to drill sites which are mandatory to maintain supply.
Implications

- The “Shale Revolution” has been a “game-changer” in that it has temporarily reversed a terminal decline in supplies from conventional sources. Long term sustainability is highly questionable and environmental impacts are a major concern.

- Almost all eggs are in the shale basket as a hope in meeting U.S. energy supply growth projections from oil and gas.

- US “Energy Independence” with the forecast energy trajectory is highly unlikely, barring a radical reduction in consumption.

- Replicating the “Shale Revolution”, to the extent it exists, will take much longer in Europe, if ever. There is no reason to expect that the geology will be much different – the greatest potential will lie in a few plays and parts thereof. Higher population densities will make surface access for the large number of drilling locations required much more difficult. Due to high population densities the collateral environmental impacts of fracking are likely to be even more apparent – and opposed – than they are in the U.S.