Shale Gas and Tight Oil: A Panacea for the Energy Woes of America?

Laufer Energy Symposium
St. Louis
April 4, 2013

J. David Hughes
Global Sustainability Research Inc.
Geological Survey of Canada - retired
The Optimism on Gas

- There is so much natural gas that there is enough available to, according to one researcher, "displace half of the coal burning power plants [in the United States] by 2020" (Pickens Plan, 2012)

- “We have the domestic natural gas necessary to fuel our trucks and fleet vehicles…” (Pickens Plan, 2012)

- Studies from prestigious energy research firms and universities have affirmed that the dream of clean, abundant, home grown energy is now reality, with the help of shale gas. (ANGA, 2012).

- The Utica Shale is “the biggest thing to hit Ohio since the plow” (Aubrey McClendon, Chesapeake, 2011).
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.

- The way is clear for substantial 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.
U.S. Gas Production versus Gas Wells Drilled per Year, 1990-2012

- **Annual Production**
- **Number of Wells per Year**

(EIA, August, 2012)
U.S. Natural Gas Supply Projection by Source, 2010-2040, EIA Reference Case 2013

- **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**

**Trillion Cubic Feet per Year**

**Year**

- **2010**
- **2015**
- **2020**
- **2025**
- **2030**
- **2035**
- **2040**

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(data from EIA Annual Energy Outlook 2013, Tables 13 and 14, [http://www.eia.gov/forecasts/aeo/er/excel/yearbyyear.xlsx](http://www.eia.gov/forecasts/aeo/er/excel/yearbyyear.xlsx))
EIA Projections of Gas Price and U.S. Production Compared to History, 1995-2040

© Hughes GSR Inc, 2012
(data from EIA Annual Energy Outlook 2013, EIA, 2012; International Monetary Fund)
U.S. Natural Gas Consumption by Sector 2009-2035 (Reference Case, EIA, 2012)

- **Electricity +30%**
- **Industrial +14%**
- **Commercial +14%**
- **Residential -3%**
- **CNG Pipeline Fuel +11%**

*16% Growth 2009-2035*


Market Share:
- Residential: 21%
- Commercial: 33%
- Industrial: 32%
- CNG Pipeline Fuel: 34%
- Electricity: 30%

(Data from Energy Information Administration Annual Energy Outlook, 2012)
Barnett Shale Production by Well Type, 2000-2012, Illustrating Impact of Horizontal Drilling Technology

93% of Production is from Horizontal Wells

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

© Hughes GSR Inc, 2013
(data from Baker-Hughes, March, 2013)
Shale Gas Production by Play, 2000-2012

Billion Cubic Feet per Day

Year

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

40% of U.S. production

Barnett
Marcellus
Haynesville

© Hughes GSR Inc, 2012

(data from DIdesktop, September, 2012, fitted with 3 month centered moving average including data up to June, 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.
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)
Haynesville Annual Production Added per New Well

Annual Production Added per Well (Thousand cubic feet per day)

Yearly Production Added per Well

Yearly Wells Added

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

Highest One Month Gas Production from Individual Wells

Highest Monthly Production (Mcf/day)

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

Percentage of Wells

© Hughes GSR Inc, 2012
(data from DI Desktop, HPDI, September, 2012)
Haynesville Well Quality - Top 20% with Highest One Month Production of >10989 mcf/day in black
Barnett Average Production per Well

Average Production per Well (Thousand cubic feet per day)

Year

Number of Wells

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

Highest One Month Gas Production from Individual Wells

Median = 1332 mcf/day
Mean = 1619 mcf/day

Highest Monthly Production (Mcf/day)

Percentage of Wells

© Hughes GSR Inc, 2012

(data from DI Desktop, HPDI, September, 2012)
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
Marcellus Well Quality - Top 20% with Highest One Month Production of >3603 mcf/day in black
Pennsylvania Marcellus Production By County

Top 2 counties = 45% of production
Top 4 counties = 67% of production
Top 6 counties = 85% of production
Estimated Ultimate Recovery for Pennsylvania Marcellus Horizontal Wells By County

- Production (billion cubic feet per day)

<table>
<thead>
<tr>
<th>County</th>
<th>Remaining Well Life</th>
<th>First 3 years</th>
<th>EIA EUR (billion cubic feet)</th>
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<tbody>
<tr>
<td>Susquehanna</td>
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<tr>
<td>Bradford</td>
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<tr>
<td>Washington</td>
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</tr>
<tr>
<td>Remaining 27 Counties</td>
<td>1.5</td>
<td>0.5</td>
<td>1.56</td>
</tr>
</tbody>
</table>

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)
## 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>
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<tr>
<td>Haynesville</td>
<td>1</td>
<td>774</td>
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<td>Approximate Well Cost (million $US)</td>
<td>Annual Well Cost to Offset Decline (million $US)</td>
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<tr>
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<td>~400</td>
<td>0.5</td>
<td>200</td>
<td></td>
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<tr>
<td>Bossier</td>
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<td>189</td>
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<tr>
<td>Bone Spring</td>
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<td>206</td>
<td>3.7</td>
<td>762</td>
<td></td>
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<tr>
<td>Austin Chalk</td>
<td>13</td>
<td>127</td>
<td>7.0</td>
<td>889</td>
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<tr>
<td>Permian Delaware Midland</td>
<td>14</td>
<td>122</td>
<td>6.9</td>
<td>842</td>
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<td><strong>Total</strong></td>
<td></td>
<td>7641</td>
<td></td>
<td><strong>41829</strong></td>
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</table>
“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
What About Shale (Tight) Oil and *Saudi America*?
U.S. Consumption of Petroleum Liquids by Source
1975-2012

Net Imports 42%
Oil 34%

Million Barrels per Day

0 5 10 15 20 25

Recessions

© Hughes GSR Inc, 2012
(data from EIA, September, 2012)
U.S. Crude Oil Production Projection by Source and Region 2010-2040 (EIA 2013 Reference Case)

- Alaska
- Onshore EOR
- Onshore Shale/Tight Oil
- Lower-48 Onshore Conventional
- Lower-48 Offshore

Peak Production 2019

© Hughes GSR Inc, 2012
(data from EIA AEO 2013 Early Release, December, 2012)
U.S. Oil Production and Number of Oil Wells Drilled Annually, 1990-2012

- **Daily Production**
- **Number of Wells per Year**

**Number of Wells Drilled per Year**

**Million Barrels per Day**

**Year**

- 1990
- 1995
- 2000
- 2005
- 2010

© Hughes GSR Inc, 2012

(data from EIA, August, 2012)
Citigroup 2012 Projection of U.S. Shale Oil, 2010-2022
(limitless well locations and no declines)

Source: Citi Investment Research and Analysis
IEA 2012 Projection of U.S. Petroleum Liquids Production, 2010-2035
(3.1 mb/d of shale oil by 2022 vs 3.7-5.0 by Citigroup)
Crude Oil and Other Liquids Production by Shale Play

Top 2 Plays = 81% of Total
Top 5 Plays = 92% of Total

(data from HPDI, September, 2012, for production in most cases through May-June, 2012)
Eagle Ford Oil Production and Number of Operating Wells, 2007-2012

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

- **Average Production per Well**
- **Number of Wells**

(Data from DrillingInfo/HPDI, March, 2013)
Eagle Ford Type Oil Well Decline Curve

First year = 64%
Second year = 45%
Third year = 78%

Oil Production (Barrels per Day)

Months on Production

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

Overall Field Decline = 38%

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

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Eagle Ford Well Quality - Top 20% with Highest One Month Production of >667 bbls/day in black
Eagle Ford Tight Oil Production vs Operating Wells

Peak at 891 Kbbls/day in 2016

Locations run out in 2016 at 11406 operating wells

Assumptions:
- Current drilling rate of 1983 wells/year maintained
- Estimate of 11406 remaining locations as of 1/1/2010 is correct
- Well quality is maintained at 2011 levels

© Hughes GSR Inc, 2012
(data from DI Desktop, HPDI, September, 2012)
Eagle Ford Tight Oil Production vs Operating Wells

Peak 1031 Kbbls/day
In 2015 if 2500 Wells added each year

Peak 891 Kbbls/day
2016 if 1983 Wells added each year

Production (Thousand Barrels per Day)

Year

Production at 1983 wells/year
Production at 2500 wells/year
Drilling Rate 1983 wells/year
Drilling Rate 2500 wells/year

© Hughes GSR Inc, 2012
(data from DI Desktop, HPDI, September, 2012)
Bakken/Three Forks Oil Production and Number of Operating Wells, 2007-2012

- **Oil Production (Thousand bbls/day)**
- **Number of Wells**

<table>
<thead>
<tr>
<th>Year</th>
<th>Oil Production</th>
<th>Number of Wells</th>
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<tr>
<td>2007</td>
<td>100</td>
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<tr>
<td>2008</td>
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<tr>
<td>2011</td>
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<td>5000</td>
</tr>
<tr>
<td>2012</td>
<td>600</td>
<td>6000</td>
</tr>
</tbody>
</table>

(data from DrillingInfo/HPDI, March, 2013)
Bakken/Three Forks Average Production per Well

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Production per Well</th>
<th>Number of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
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<td>2012</td>
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</tr>
</tbody>
</table>

© Hughes GSR Inc, 2013
(data from DrillingInfo/HPDI, March, 2013)
Bakken/Three Forks Horizontal Well Type Decline Curves including North Dakota and Montana

- Oil and Gas production (Barrels oil equivalent)
- Oil Production (Barrels)
- Gas Production (Mcf)

Oil
- First year = 70%
- Second year = 36%
- Third year = 24%
- Fourth year = 19%

(data from DrillingInfo/HPDI, March, 2013)
Overall Field Decline for Bakken/Three Forks Oil Production based on Production Decline from pre-2012 Wells

Overall Field Decline = 44%

(data from DrillingInfo/HPDI, March, 2013)
Bakken Well Quality - Top 20% with Highest One Month Production of >589 bbls/day in black
Horizontal Well Development in the Parshall Area
Sweet Spot of the Bakken

© Hughes GSR Inc, 2013
(data from North Dakota DNR, 2013)
Bakken/Three Forks Production By County, North Dakota and Montana

Total Production = 694 Kbbls/day
Top 2 counties = 52% of production
Top 4 counties = 85% of production

Production ( Thousand Barrels per day)

- Montrail
- Mckenzie
- Williams
- Dunn
- Remaining counties 9
- Montana
Bakken/Three Forks Type Decline Curves for Horizontal Wells by County including Montana

Overall Average Oil
First year = 70%
Second year = 36%
Third year = 24%
Fourth year = 19%

(data from DrillingInfo/HPDI, March, 2013)
Bakken/Three Forks Estimated Ultimate Recovery per Well By County, North Dakota and Montana

EIA ASSUMES 550 KBBLs ULTIMATE RECOVERY FOR ALL WELLS

All wells hit stripper status within 12-25 years (10 barrels per day)
The 10% terminal decline assumed is likely highly optimistic

© Hughes GSR Inc, 2013
Bakken Shale Oil Production vs Operating Wells

Peak 973Kbbls/day in 2017

Locations run out in 2017 at 11725 operating wells

Assumptions:
- Current drilling rate of 1500 wells/year maintained
- EIA estimate of 9767 remaining locations as of 1/1/2010 is correct
- Well quality is maintained at 2011 levels

Production (Thousand Barrels per Day)

Number of producing wells

Year

© Hughes GSR Inc, 2012
(data from DI Desktop, HPDI, September, 2012)
Bakken Shale Oil Production vs Operating Wells

- Peak 1099 Kbbls/day in 2015 if 2000 Wells added each year
- Peak 973 Kbbls/day in 2017 if 1500 Wells added each year

- Production at 1500 wells/year
- Production at 2000 wells/year
- Drilling Rate 1500 wells/year
- Drilling Rate 2000 wells/year

(data from DI Desktop, HPDI, September, 2012)
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.
Summary and Implications

• The Shale Revolution has been a “game-changer” in that it has averted a terminal decline in supplies from conventional sources.

• Almost all eggs are in the shale basket as a hope in meeting supply growth projections.

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

• The “Shale Revolution” has provided a temporary respite from declining oil and gas production but should not be viewed as a panacea for increasing energy consumption – and exporting the bounty - rather it should be used as an opportunity to create the infrastructure needed for a lower energy throughput and alternative energy sources.
More Info:

http://www.postcarbon.org/reports/DBD-report-FINAL.pdf