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.

© Hughes GSR Inc, 2012
U.S. Gas Production versus Gas Wells Drilled per Year, 1990-2012

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

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

55% increase in production by 2040

U.S. Domestic consumption

Shale Gas

Coalbed Methane

Tight Gas

Associated

Conventional

Offshore

LNG Imports

Canada Imports

Alaska

Conventional

Offshore

Canadian Imports

Exports

50% of 2040 Production

Trillion Cubic Feet per Year

Year

2010

2015

2020

2025

2030

2035

2040

© Hughes GSR Inc, 2012

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

Gas Price ($US/mcf)

- 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

Year

Annual Gas Production (Trillion cubic feet)

(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)

Market Share

Electricity +30%
Industrial +14%
Commercial +14%
Residential -3%

16% Growth 2009-2035

© Hughes GSR Inc, 2012
(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

© Hughes GSR Inc, 2012 (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)
Shale Gas Production by Play

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

Billion Cubic Feet per Day

Haynesville, Barnett, Marcellus, Fayetteville, Eagle Ford, Woodford, Bakken, Niobrara, Antrim, Bossier, Bone Spring, Austin Chalk, Permian, Lewis, Mancos, Spraberry, Mississippip Lime, Bend, Pearsall, Utica, Hermosa, Pierre, Tuscaloosa, Manning, New Albany, Mulky, Chattanooga, Mowry, Cody

(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 Gas Production and Number of Operating Wells, 2007-2012

Gas Production (Billion cubic feet per day)

- Gas Production
- Number of Wells

Year

Number of Operating Wells

© Hughes GSR Inc, 2013
(data from DrillingInfo/HPDI, March, 2013)
Haynesville 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)
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 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 Well Quality - Top 20% with Highest One Month Production of $>10989$ mcf/day in black
Barnett Average Production per Well

© 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

- Production from pre-2012 Wells
- Number of 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
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 Shale Gas Production vs Wells by State

- Pennsylvania Production
- West Virginia Production
- Total Production
- Pennsylvania Wells
- West Virginia Wells
- Total Wells

Pennsylvania Production
West Virginia Production
Total Production

© Hughes GSR Inc, 2013
Pennsylvania Marcellus Daily Well Production by Well Type

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

© Hughes GSR Inc, 2013
Pennsylvania Marcellus Production Added per Horizontal Well

- Yearly Production Added per Well
- Yearly Wells Added

© Hughes GSR Inc, 2013
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

Production (billion cubic feet per day)

- Bradford
- Susquehanna
- Lycoming
- Greene
- Tioga
- Washington
- Fayette
- Remaining 26 Counties

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

- 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

<table>
<thead>
<tr>
<th>County</th>
<th>Estimated Ultimate Recovery (Bcf)</th>
<th>Remaining Well Life</th>
<th>First 3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Susquehanna</td>
<td>4.5</td>
<td>2.1</td>
<td>2.4</td>
</tr>
<tr>
<td>Bradford</td>
<td>4.0</td>
<td>1.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Lycoming</td>
<td>3.5</td>
<td>1.6</td>
<td>1.9</td>
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<tr>
<td>Greene</td>
<td>3.0</td>
<td>1.2</td>
<td>1.8</td>
</tr>
<tr>
<td>Tioga</td>
<td>2.5</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Washington</td>
<td>2.0</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Remaining 27 Counties</td>
<td>1.5</td>
<td>0.5</td>
<td>1.0</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>
</tr>
</thead>
<tbody>
<tr>
<td>Haynesville</td>
<td>1</td>
<td>774</td>
<td>810</td>
<td>20</td>
<td>Decline</td>
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<tr>
<td>Barnett</td>
<td>2</td>
<td>1507</td>
<td>1112</td>
<td>42</td>
<td>Decline</td>
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<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>
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<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>
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<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>
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© 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>
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<tbody>
<tr>
<td>Haynesville</td>
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<td>774</td>
<td>9.0</td>
<td>6966</td>
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<tr>
<td>Marcellus</td>
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<td>561</td>
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<td>2525</td>
</tr>
<tr>
<td>Fayetteville</td>
<td>4</td>
<td>707</td>
<td>2.8</td>
<td>1980</td>
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<tr>
<td>Eagle Ford</td>
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<td>945</td>
<td>8.0</td>
<td>7558</td>
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<tr>
<td>Woodford</td>
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<tr>
<td>Granite Wash</td>
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<td>239</td>
<td>6.0</td>
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<tr>
<td>Bakken</td>
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<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>
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<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>

(Well cost data from various sources and is approximate)
The Reality Check

"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%
Recessions

Net Imports
Natural Gas Liquids
Refinery Gains
Oil

© 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**: Peak Production 2019
- **Onshore EOR**: 32% of 2040 Supply
- **Onshore Shale/Tight Oil**:
- **Lower-48 Onshore Conventional**:
- **Lower-48 Offshore**:

(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**

U.S. Oil Production and Number of Oil Wells Drilled Annually, 1990-2012 (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**

© Hughes GSR Inc, 2013

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

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

(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%

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

Production (Thousand Barrels per Day)

Year

© 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

© 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 Operating Wells**

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

Montrail
Mckenzie
Williams
Dunn
Remaining counties
Montana

© Hughes GSR Inc, 2013
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

The 10% terminal decline assumed is likely highly optimistic.

EIA ASSUMES 550 KBBLS ULTIMATE RECOVERY FOR ALL WELLS

All wells hit stripper status within 12-25 years (10 barrels per day)

© 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

© 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