Shale Gas and Shale Oil

Mountain or Molehill?

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Outline

- The Energy Challenge
  - People, Economy and Carbon
- Unconventional Oil and Gas
  - To “Frack” or Not to “Frack”
- Options to Oil and Gas
  - Nothing is Perfect
Global Population and Energy

Population (millions)

Primary energy (quads)

Energy demand is about people

http://www.eia.gov/iea/wecbtu.html
TPER = Total Primary Energy Requirement. Energy needed to facilitate Total Final Consumption (TFC does not include conversion and transmission losses).

After: Rice World Gas Trade Model
Medlock, 2012
U.S. Economy and Oil Price

GDP Growth (% change on 2000 chained dollars)

Year


Oil Domestic Wellhead Price (2010 $)

Data: EIA and BP Statistical Analysis; US Department of Commerce
http://www.bp.com/sectiongenericarticle800.do?categoryId=9037172&contentId=7068612
1970-1983 Arabian Light 1984-2010 Brent dated
Energy and the economy are linked.
The Global Carbon Challenge

Source: Lawrence Livermore National Laboratory and U.S. DOE based on Annual Energy Review, 2008 (EIA, 2009)
From National Academies Press, America’s Energy Future, 2009

(U.S. Energy 2008 Quads)
Source: Lawrence Livermore National Laboratory and U.S. DOE based on Annual Energy Review, 2008 (EIA, 2009)
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The Global Carbon Challenge

North America

Europe

Asia Pacific

Quadrillion BTUs

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U.S. Natural Gas

Production and Reserves

After Steve Harvey, EIA
Hydraulic Fracturing
“Fracking”

3,000 to 10,000+ feet

3,000 – 10,000 feet

Shale
Innovation driven by necessity

Barnett drilling location
University of Texas at Arlington

From XTO annual report
U.S. Gas Shale Production

5 Tcf/y today

Model: Rice University, Medlock, 2012


Annual shale gas production, Tcf

<table>
<thead>
<tr>
<th>Year</th>
<th>Eagle Ford Shale</th>
<th>Marcellus Shale</th>
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<tbody>
<tr>
<td>0.0</td>
<td>Barnett and Woodford Shale</td>
<td>Fayetteville Shale</td>
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<tr>
<td>1.0</td>
<td>Antrim Shale</td>
<td>Haynesville-Bossier Shale</td>
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<tr>
<td>2.0</td>
<td>Pawnee-Shale</td>
<td>Marcellus Shale</td>
</tr>
<tr>
<td>3.0</td>
<td>New York (Utica) Shale</td>
<td>Woodford Arkoma &amp; Ardmore Shale</td>
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<tr>
<td>4.0</td>
<td>Berea Shale</td>
<td>Navorra Shale</td>
</tr>
<tr>
<td>5.0</td>
<td>Naborara Shale</td>
<td>Paradox &amp; Uinta Shale</td>
</tr>
<tr>
<td>6.0</td>
<td>Paradox &amp; Uinta Shale</td>
<td>Hilliard/Baxter/Mowry Shale</td>
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<tr>
<td>7.0</td>
<td>Hilliard/Baxter/Mowry Shale</td>
<td>Lewis &amp; Mancos Shale</td>
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<tr>
<td>8.0</td>
<td>Lewis &amp; Mancos Shale</td>
<td>Bakken Shale</td>
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<tr>
<td>9.0</td>
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<td>Felippone &amp; Chatanooga Shale</td>
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<tr>
<td>10.0</td>
<td>Felippone &amp; Chatanooga Shale</td>
<td>Catskill-Big Sandy Shale</td>
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<td>12.0</td>
<td>Nora Haysi-Devonian Shale</td>
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<td>Berea Shale</td>
<td>NW Ohio Shale</td>
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<td>NW Ohio Shale</td>
<td>Marcellus Shale</td>
</tr>
<tr>
<td>15.0</td>
<td>Marcellus Shale</td>
<td>New York (Utica) Shale</td>
</tr>
</tbody>
</table>
### U.S. Gas Shale Production

**Year** | **Eagle Ford Shale** | **Marcellus Shale** | **Haynesville-Bossier Shale** | **Barnett Shale** | **Antrim Shale** | **Woodford Shale** | **Fayetteville Shale** | **Model: Rice University, Medlock, 2012**
---|---|---|---|---|---|---|---|---
2000 | 5.0 Tcf/y today | 4.5 Tcf/y today | 4.0 Tcf/y today | 3.5 Tcf/y today | 3.0 Tcf/y today | 2.5 Tcf/y today | 2.0 Tcf/y today | 1.5 Tcf/y today | 1.0 Tcf/y today | 0.5 Tcf/y today | 0 Tcf/y today | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 |
Cumulative Production: First 24 Months
Natural Gas Wells, 1983-2011
Barnett Shale, TX

Map Produced 8/2012
North American shale plays (as of May 2011)

Potential Global Shale Gas Basins

- Landowner Royalty: Mixed
- Negative
- Positive

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Unconventional Reservoirs

Implications

- Environmental
  - Traffic/noise/light
  - Water
  - Land Use
  - NORM
  - Methane
  - Quakes
  - Carbon

- Energy Security
  - Available
  - Affordable
  - Reliable
  - Clean
US Oil Production (BOPD)

US Oil Production (BOPD)

Source: EIA

- Net petroleum imports: 60% reduction by 2010, 49% by 2035
- Consumption: 36% reduction by 2010, maintained until 2035

U.S. SHALE LIQUIDS PROJECTIONS

3.8 mmb/d by 2022...

U.S. shale liquids projected growth (Mbpd)

After Morse et. al., 2012, Energy 2020: North America, the new Middle East: Citi GPS: Global Perspectives & Solutions, figure 14, p. 17.

IRR Source: Rystad Energy
1.4 bby shale oil by 2022

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Natural Gas Supply - Resources and Production

Options to Natural Gas for Power

I. Coal
   - Available, affordable to generate, reliable
   - Dirty, expensive to build

II. Nuclear
   - Powerful, efficient, no emissions, affordable to generate
   - Expensive to build, waste, safety

III. Wind
   - Simple, affordable, no emissions
   - Intermittent, land and visual, transmission

IV. Solar
   - Simple, no emissions, local
   - Expensive, intermittent, inefficient

V. Hydro
   - Efficient, affordable to generate, no emissions
   - Water, land, supply

VI. Geothermal
   - Affordable where concentrated, no emissions
   - Expensive everywhere else, energy density
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No form of energy is perfect
Oil Supply

Resources and Cost

Oil Supply
Resources and Cost

Oil will be more expensive

Options to Oil for Transport

No form of energy is perfect

I. Biofuels
   - Valuable supplement, lower carbon
   - Scale, land use, cost
   - Soil science, hydrogeology, fertilizers, weather, climate

II. CNG, LPG, LNG, GTL
   - Cleaner than oil, regionally cheap, available
   - Dirtier than others, regionally expensive

III. Electricity
   - Clean depending on source, efficient engine
   - Expensive, chemicals, range

IV. Hydrogen
   - Ten years away
A Look at the Global Future

Tinker Forecast

- Petroleum Consumption
- Coal Consumption
- Natural Gas Consumption
- Nuclear Electric Power Consumption
- Hydroelectric Power Consumption
- Biomass, Geothermal, Solar & Wind Consumption

Petroleum Consumption: 45%
Coal Consumption: 15%
Natural Gas Consumption: 20%
Nuclear Electric Power Consumption: 10%
Hydroelectric Power Consumption: 10%
Biomass, Geothermal, Solar & Wind Consumption: 0%
A Look at the Global Future

Tinker Forecast

Global Consumption (Q)
A Look at the Global Future

Global Consumption (Q)

- 70% in 1980
- 30% in 2012
- 40% in 2050
- 60% in 2080

Tinker, 2012
Energy transitions take time

- Petroleum Consumption
- Coal Consumption
- Natural Gas Consumption
- Nuclear Electric Power Consumption
- Hydroelectric Power Consumption
- Biomass, Geothermal, Solar & Wind Consumption
Energy transitions take time