The Impact of U.S. Shale Resources: A Global Perspective

by

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Outline

- Global Perspective
- U.S. Shale Resource Studies
- Implications
# Energy Security

<table>
<thead>
<tr>
<th>Affordability</th>
<th>Cost</th>
<th>Price Volatility</th>
<th>Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affordable</td>
<td>per unit of energy</td>
<td>stable or fluctuating</td>
<td>cost to build the plant</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Availability</th>
<th>Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available</td>
<td>substantial resources</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reliability</th>
<th>Intermittent</th>
<th>Safe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliable</td>
<td>source consistent or variable</td>
<td>natural/human causes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sustainability</th>
<th>Clean</th>
<th>Dense</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable</td>
<td>air and atmospheric emissions</td>
<td>energy per area, weight and volume</td>
<td>fresh water use/risk</td>
</tr>
</tbody>
</table>
Global Population
Each color on the map represents ~ 1 billion people

Modified from: EIA

Million Tonnes Oil Equivalent (2012)

Global Energy Mix

2016

-6 %
+ 1%
+ 2%
+ 3%
-33%
-32%
-33%
-32%
-352%
-351%
-351%
-351%
-351%
Integrated Study Workflow

**Geologic Analysis**
- Reservoir characterization
- Original-Resource-in-Place mapping

**Well Decline Analysis**
- Production and its decline for gas/oil/water
- Stimulated/drained rock volume

**Recovery and Productivity**
*Statistical Analysis*
Expected production *as a function of*
- Well productivity drivers,
- Location and Completion,
- Inventory of future wells,
  - Technically Recoverable Resources

**Well Economics**
Expected well profitability *as a function of*
- Well production profile,
- Operational,
- Market and regulatory parameters

**Production Outlook**
- Pace of drilling *by year and area*,
  - Expected gas/oil/water production *
    depending on economics, technology, regulation*
Effect of Completions of Expected Recovery

Major producing regions in Marcellus

average well EUR for a given region (Bcf)

EURs assuming the same completion
EUR with a preferred completion

0 1 2 3 4 5 6 7 8
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Major producing regions in Marcellus
Production Profiles by Tier

Production rate, MMcf/d

Year of production

- Barnett 1
- Barnett 2
- Barnett 3
- Barnett 4
- Barnett 5
- Barnett 6
- Barnett 7

~ \( q_0/t^c \)

30-year production projection (Bcf), based on the average 4,000 ft horizontal well.
Distributions of Individual Well Recovery

Relative frequency vs. Length normalized EUR (horizontal wells only), Bcf

- Barnett
- Fayetteville
- Haynesville

Ikonnikova et al., 2015
New Completion Strategies

Ikonnikova et al., 2016

• Established drilling patterns rapidly change owing to resource exhaustion, technological advances and new economic realm

• New drilling and completion techniques also affect the use of other resources, i.e. water, land, proppants

Practices like infill drilling and cluster drilling already change our views on the future play recovery and aggregate production possibilities.
New Features

Well economics in the past was very sensitive to D&C costs in particular, so operators get smarter about:

- Energy prices: Futures Strips / Hedging,
- Economies of scale with a multi-well pads and joint leases,
- Gathering & transportation costs: develop more efficient solutions,
- Water demand and processing of produced water
<table>
<thead>
<tr>
<th>Region</th>
<th>Resource-in-Place</th>
<th>Technically Recoverable</th>
<th>In-Place</th>
<th>Recoverable</th>
<th>Demand '15</th>
<th>Demand '05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnett</td>
<td>14,544</td>
<td></td>
<td>3100</td>
<td>700</td>
<td>27</td>
<td>22</td>
</tr>
<tr>
<td>Marcellus</td>
<td>6,934</td>
<td></td>
<td>5,834</td>
<td>27</td>
<td>7.1</td>
<td>7.6</td>
</tr>
<tr>
<td>Eagle Ford</td>
<td>12,346</td>
<td></td>
<td>3,490</td>
<td>27</td>
<td>7.1</td>
<td>7.6</td>
</tr>
<tr>
<td>Fayetteville</td>
<td>5,834</td>
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<td></td>
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</tbody>
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<thead>
<tr>
<th>Type</th>
<th>Tcf</th>
<th>Bbl</th>
</tr>
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<tbody>
<tr>
<td>Gas</td>
<td>3100</td>
<td>450</td>
</tr>
<tr>
<td>Recoverable</td>
<td>700</td>
<td>27</td>
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From the Past into the Future

New Advances

- Improved geologic resource characterization and assessment:
  - Higher fracturing efficiency: greater energy return on water and proppant used
  - Increased resource recovery: drilling into several sub-horizons

- Advances in well engineering and drilling:
  - Greater subsurface area developed from one pad with longer laterals and wells placed closer vertically and spatially
  - “Surface” use is more condensed in time and spatially

Uncertainty in parts may decrease, but in total is still high
The Future Electricity Mix

Electricity Generation by Fuel

North America

Europe

Asia Pacific

Economic and Environmental Implications

- **Economics**
  - High prices stimulated resource exploration and development
  - Low prices pushed technology and cost efficiency through scale/intensity
  - With large scale operational risks, e.g. spills or gas, are more costly
  - Higher risks lead to investments in safety and infrastructure

- **Environment**
  - Low prices and weak economics makes producers vulnerable to regulatory risks
  - Operators “preempt” regulations with acceptable solutions in advance
World Learns from Us: Will We leave Positive Legacy

- Environmental concerns, particularly about land use and water resources, motived operators to improve
  - Subsurface-to-surface ratio
  - Water handling
  - Spill and leakage protection
  - Local communities involvement
Key Insights

- **Economy-wide implications:**
  - Emissions reduction supported by increasing natural gas supply and low prices
  - Job creation in upstream, midstream, services and more
  - U.S. manufacturing growth owing to affordable and reliable natural gas

- **Unconventional resources are very heterogeneous**
  - Each play is different and there are no “best” recipe

- **Industry is very dynamic**
  - Technology, players, and concerns continuously change

- **We will continue our path forward into the bright future and shale resource will support it!**
Shaping Further Conversation

- Discussion about future development must include major stakeholders, land owners/communities, regulators and producers, supported by:
  - Comprehensive information and data collection/interpretation
  - Understanding of each party interests and responsibilities
  - Longer planning horizon to motivate investments with efficiency

- Lessons about Integration
  - Consistency
  - Integrity
  - Transparency
  - Communication
Energy security dictates the energy mix.

- Oil and coal are secure and difficult to replace.
- Natural gas and nuclear are scalable, and cleaner.
- Renewables are growing regional supplements.
- Energy efficiency has major benefits.

Take the long-term view and keep the perspective.
Thanks!