Fracking Safety & Economics

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Fracking Fears, Perceptions Vs Reality

Simplistic Fracking Overview

“Public Fracking Concerns”
- Groundwater Contamination.
- Earthquakes from “fracking”.
- Industrial Impacts.

My “Fracking” Concerns

Surface Spills - Inherent risk to any industrial process.
  Solution - Consistent improvement due to better management practices.

Job Safety – Worker Protection – Always a concern in any high pressure, high volume operation.
  Solution – The FAA/Airline “ASAP” accident & reporting system.

Earthquakes from waste water injection conducted above the fracture propagation pressure. Unrelated to the physical fracturing process for oil and gas production.
  Solution: Increased recycling of liquid wastes versus deep injection close to tectonically active or sensitive areas.

Realistic Fracking Overview

https://www.greenandgrowing.org/hydraulic-fracking-process/
<table>
<thead>
<tr>
<th>Perception</th>
<th>Reality</th>
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<tbody>
<tr>
<td>Fracking is just below my groundwater – contamination occurs all the time.</td>
<td>Fracking is thousands of feet to miles below the groundwater aquifers.</td>
</tr>
<tr>
<td>There is no control of the process, the fractures can go “anywhere”.</td>
<td>Rock mechanics, earth stress models are used to keep the frac within the desired zone.</td>
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<tr>
<td>The industrial foot print remains for the life of the well.</td>
<td>The drilling operation per well takes days, and the time to drill up a multi-well pad is measured in months.</td>
</tr>
<tr>
<td>Earthquakes! My home and land is at risk.</td>
<td>Minor quakes associated with the initial fracking – too small to be detected without a seismograph - do occur. Subsequent production actually lowers stress and pressure and in many cases reduces the probability of future quakes.</td>
</tr>
</tbody>
</table>
So how is my Groundwater Protected?

- At least two cemented and tested steel casings separate the fracking & production process from groundwater.

Surface Casing
- Production or Intermediate Casing.

- Strength of the bond between the rock – cement – steel casing is measured prior to drilling the subsequent zones. Fracking and Production pressure loads do not exceed the bond.

- Acoustic bond logs are run to ensure the cement is bonded to both the steel casing and the formation, prior to the actual Fracking process.

- Fracking of the tight oil or gas zone is performed in stages to ensure control of the frac to the desired zone, frac length, and proppant placement.
  - Actual fracking is thousands of vertical feet away from groundwater.
  - Tracers can be used to verify proper fracture growth and proppant placement.

Base Graphic www.azomining.com/Article.aspx?ArticleID=18
What about Earthquakes & Fracking?

**ROCK MECHANICS 101**

- All Sedimentary Rocks consist of grains (clay – silt – sand) and pore space – the pore space is occupied by water, gas or oil.
- All rocks have to support the “stuff above” – aka the overburden.
- The load due to overburden is counteracted by two forces:
  - Fluid pressure in the pore space of the rock.
  - Point loading of the rock grains (sand or silt).

**Hydraulic Fracturing**

- Applied pressure must be greater than the point loading or grain stress in the rock (shale or sandstone).
- Once the rock fractures the grain stress in the surrounding rocks increases and can induce local mini fracs away from the actual induced fracture network.
- This local increased stress can induce minor earthquakes. Typically only felt on seismographs, and have no impact on the surface.

**Long Term Impact**

- Once the well produces a volume of gas and liquids (gas, condensate, oil, water) greater than the volume injected during the fracturing process, the combination of fluid pressure and grain stress will be lower than the initial state.
- Regional Quake risk may actually decrease long term.
In terms of Oil resources the US is a lot like Venezuela – we have the resources. But do we really have the reserves?

**Resources are not Reserves**

Resource is what is physically there,

Reserves are the portion of the resource that can be economically produced.

Resources are only the first step to dominance, in the end Reserves are what really matter.

Does the US only have “Big” reserves intermittently in high price environments? Or, can US Shale Oil compete at lower prices…… and how low, is low?
US Shale Oil, Projected Reserves... if Economic...are Massive

Source: BP Statistical Review of World Energy 2017

### Reserves-to-production (R/P) ratios

#### 2016 by region

<table>
<thead>
<tr>
<th>Country - Region</th>
<th>Bln Bbls Proved Reserves</th>
<th>Share %</th>
<th>R/P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Venezuela</strong></td>
<td>72.7 87.3 300.9 300.9</td>
<td>16.3%</td>
<td>341.1</td>
</tr>
<tr>
<td><strong>Saudi Arabia</strong></td>
<td>261.4 264.3 266.6 266.5</td>
<td>14.5%</td>
<td>59.0</td>
</tr>
<tr>
<td><strong>USA</strong></td>
<td>48.9 121.9 90.9 110.0</td>
<td>9.9%</td>
<td>40.4</td>
</tr>
<tr>
<td><strong>Canada</strong></td>
<td>48.9 179.4 171.5 171.5</td>
<td>9.3%</td>
<td>105.1</td>
</tr>
<tr>
<td><strong>Iran</strong></td>
<td>92.6 138.4 158.4 158.4</td>
<td>8.6%</td>
<td>94.1</td>
</tr>
<tr>
<td><strong>Iraq</strong></td>
<td>112.0 115.0 142.5 153.0</td>
<td>8.3%</td>
<td>93.6</td>
</tr>
<tr>
<td><strong>Russia</strong></td>
<td>113.6 104.0 102.4 102.4</td>
<td>5.9%</td>
<td>20.0</td>
</tr>
<tr>
<td><strong>Kuwait</strong></td>
<td>96.5 101.5 101.5 101.5</td>
<td>5.5%</td>
<td>88.0</td>
</tr>
<tr>
<td><strong>United A.E</strong></td>
<td>97.8 97.8 97.8 97.8</td>
<td>5.3%</td>
<td>65.6</td>
</tr>
<tr>
<td><strong>Libya</strong></td>
<td>29.5 41.5 48.4 48.4</td>
<td>2.6%</td>
<td>310.1</td>
</tr>
<tr>
<td><strong>Nigeria</strong></td>
<td>20.8 37.2 37.1 37.1</td>
<td>2.0%</td>
<td>49.3</td>
</tr>
<tr>
<td><strong>Kazakhstan</strong></td>
<td>5.3 9.0 30.0 30.0</td>
<td>1.6%</td>
<td>49.0</td>
</tr>
<tr>
<td><strong>China</strong></td>
<td>16.4 20.2 25.7 25.7</td>
<td>1.4%</td>
<td>17.5</td>
</tr>
<tr>
<td><strong>Qatar</strong></td>
<td>3.7 27.4 25.2 25.2</td>
<td>1.4%</td>
<td>36.3</td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td>6.7 12.2 13.0 12.6</td>
<td>0.7%</td>
<td>13.3</td>
</tr>
<tr>
<td><strong>Algeria</strong></td>
<td>10.8 12.3 12.2 12.2</td>
<td>0.7%</td>
<td>21.1</td>
</tr>
<tr>
<td><strong>Angola</strong></td>
<td>3.7 9.0 11.8 11.6</td>
<td>0.6%</td>
<td>17.5</td>
</tr>
<tr>
<td><strong>Mexico</strong></td>
<td>48.5 12.8 8.0 8.0</td>
<td>0.4%</td>
<td>8.9</td>
</tr>
<tr>
<td><strong>Ecuador</strong></td>
<td>3.5 4.5 8.0 8.0</td>
<td>0.4%</td>
<td>40.1</td>
</tr>
<tr>
<td><strong>Norway</strong></td>
<td>11.7 8.5 8.0 7.6</td>
<td>0.4%</td>
<td>10.4</td>
</tr>
<tr>
<td><strong>Other(34)</strong></td>
<td>62.9 77.0 74.6 73.3</td>
<td>4.0%</td>
<td>28.1</td>
</tr>
<tr>
<td><strong>Total World</strong></td>
<td>1,149 1,388 1,692 1,842</td>
<td>100.0%</td>
<td>50.6</td>
</tr>
</tbody>
</table>

The US & Canadian proved reserves rival or exceed Saudi Arabia.

The US & Canadian R/P ratio is competitive with the Middle East.
1st Question - What is the “Reserve Basis” Oil Price?

The “Average Joe” Oil Price
Inflation Adjusted Average Oil Price over the last 40 yrs =?

Answer = $50-$55/Bbl

Adjust Cost Structure to Fit a $40-$50 Bbl World and Move on.
Can the US Oil Shale Resource = Reserves @ $40-$50/Bbl?

ANSWER: – Trends say “Yes, we can”.

Source: Department of Energy, US EIA
Initial or Flush Production from Shale wells is very impressive. However, the drop from the peak is quite fast and dramatic. The long term “Tail” production is typically only a fraction of the initial Flush production.

Source: U.S. Energy Information Administration, *Drilling Productivity Report*
Fracking CW – Why The Flush Production – Then Decline?

- In Oil Shale deposits the rock has a low permeability.
- Over millions of years the rock is stressed & cracks.
- Oil seeps into cracks, but the oil has not migrated out of the shale rock layer.

Horizontal wells drilled & fracked along the shale layers, connect the fractures & produce the “fracture oil” very well.

Once the “flush oil” from the fractures is depleted, the oil in the shale itself flows out very slow.

…thus a rapid drop in production…
and the long production tail
So what are the recent trends in Oil Shale Well Production?

**U.S. NEW-WELL OIL PRODUCTION PER RIG (BBL/D) KEEPS RISING**

- Oil Barrels per Rig (New Wells Only) [Rig Productivity]
  - Permian
  - Eagle Ford
  - Bakken

Same Initial new well production data.

New well initial production

Huge gains in 2016 and sustained in 2017, but have we reached a maximum?

More importantly are we adding new reserves or simply accelerating oil forward in time?

If these productivity gains can be sustained and represent additional oil reserves….then the US can and will DOMINATE Shale oil on a global basis.
US surge in oil production continues, led by the Permian Basin & Baken as both remain economic at $40-$50 / Bbl.

The “Fracking Impact” – Horizontal Fracs in “Tight Oil” Reservoirs

8/8/17 EIA Projection for 2018 = 9.91 MM BOPD
How well do we understand the “Tight OIL & Gas” Play?

ANSWER:
Not as well as we should.

Solution:
America’s Universities are pivoting towards fundamental research to understand how to unlock America’s Tight Oil and Gas Resource.
Fracking is safe and has the potential to unlock a vast resource of domestic oil and gas to enable America to not meet America demand, but to export globally on a significant scale.

Fracking Economic trends indicate America’s tight oil and gas resources remain viable even at oil prices in the 40-50 $/Bbl range.

Long term (3-5 yrs from initial production) well production – uncertainties remain. New technologies / understandings are need to further add value and security to America’s oil and gas future.
Back-Up Slides
What if.....the rest of the world starts Fracking?

- Potential US "dominance" in oil would be mitigated by similar shale oil developments on a global basis.
- Possible – Yes. Likely - No
Why the USA is the Fracking leader and is likely to continue.

• **The USA mineral rights/ownership model is unique in the world.** Outside the US, the owner of the surface land – be it a house or farmland – has absolutely no rights with regards to mineral ownership.

• Not so in the US, **61% of US Land & Minerals are privately held** and the landowner/mineral rights owner owns the minerals. **The individual shares in the financial returns associated with oil and gas development.**

• Canada has equally impressive shale oil/gas resources, however only 9% of the Canadian mineral rights are privately held.

• With little to no financial incentive to deal with the temporary surface impacts associated with drilling and production **outside the US,** there is also relatively **little global support for fracking** and oil and gas development.

• The **mineral rights structure in the US supports a diverse range of oil and gas companies** that work in competitive as well as a complimentary modes. Outside the US the oil and gas industry is dominated almost entirely by large corporations and national oil companies.

• The end result is the **US enjoys the most diverse, efficient and safe oil and gas industry in the world.**

• Rotary drilling on land & offshore drilling started and to a large degree remain US based*. The Fracking revolution will follow the same US led path.

Thus, a reserves position based on onshore fracking is likely to remain a globally competitive advantage for the US.