Trends in U.S. Shale Completions

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Outline:

1. U.S. Oil & Gas Production – Economic Impact of Shale
2. Enabling Technologies: Fracturing, Directional Drilling
3. Shale Completion Trends
4. Water Use in Completions
5. Water Treatment
6. Waterless Alternatives
U.S. Shale Oil & Gas Activity Map

2103 Active Rigs
1385 Horizontal - 66%
18 million HHP Frac
530 Frac Fleets
U.S. Oil & Gas Shale Production

U.S. crude oil production
million barrels per day

History 2012 Projections

U.S. maximum production level of 9.6 million barrels per day in 1970

Tight oil

Lower 48 offshore

Alaska

Other lower 48 onshore

Source: EIA
# Global Potential for Shale Oil & Gas

## Shale Oil

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Billion Barrels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Russia</td>
<td>75</td>
</tr>
<tr>
<td>2</td>
<td>United States</td>
<td>58</td>
</tr>
<tr>
<td>3</td>
<td>China</td>
<td>32</td>
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<tr>
<td>4</td>
<td>Argentina</td>
<td>27</td>
</tr>
<tr>
<td>5</td>
<td>Libya</td>
<td>26</td>
</tr>
<tr>
<td>6</td>
<td>Venezuela</td>
<td>13</td>
</tr>
<tr>
<td>7</td>
<td>Mexico</td>
<td>13</td>
</tr>
<tr>
<td>8</td>
<td>Pakistan</td>
<td>9</td>
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<tr>
<td>9</td>
<td>Canada</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>Indonesia</td>
<td>8</td>
</tr>
<tr>
<td><strong>World Total</strong></td>
<td><strong>345</strong></td>
<td></td>
</tr>
</tbody>
</table>

## Shale Gas

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Trillion Cubic Feet</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>1,115</td>
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<tr>
<td>2</td>
<td>Argentina</td>
<td>802</td>
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<td>3</td>
<td>Algeria</td>
<td>707</td>
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<td>4</td>
<td>United States</td>
<td>665</td>
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<tr>
<td>5</td>
<td>Canada</td>
<td>573</td>
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<td>6</td>
<td>Mexico</td>
<td>545</td>
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<td>7</td>
<td>Australia</td>
<td>437</td>
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<td>8</td>
<td>South Africa</td>
<td>390</td>
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<tr>
<td>9</td>
<td>Russia</td>
<td>285</td>
</tr>
<tr>
<td>10</td>
<td>Brazil</td>
<td>245</td>
</tr>
<tr>
<td><strong>World Total</strong></td>
<td><strong>7,299</strong></td>
<td></td>
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</table>

Source: EIA
# The Eagle Ford Formation

<table>
<thead>
<tr>
<th>Marquis</th>
<th>Palmetto</th>
<th>Cotulla-Wyco</th>
<th>Cotulla-LaSalle/Frio</th>
<th>Catarina</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

- **Upper Eagle Ford**
- **Lower Eagle Ford Target 1**
- **Lower Eagle Ford Target 2**
- **Buda**
The Eagle Ford Formation in Texas
Oil & Gas Companies in the Eagle Ford

Thousand acres

EOG Resources
Chesapeake
BHP Billiton
Sanchez Energy Corp.
BP
Lewis Energy
CNOOC
ConocoPhillips
Marathon Oil
SM Energy

- Oil
- Condensate
- Gas
Typical Eagle Ford Hydraulic Fracturing Site
Trends in U.S. Completions; and Eagle Ford

- **Lowering Costs by:**
  - Zipper Fracturing on pad locations
  - Optimizing proppant logistics (rail, trans-loading, trucking)
  - Fuel substitution (CNG, LPG, line gas for diesel)
  - “Increased use of slickwater fluids

- **Improving well production by:**
  - “Engineered” completions using LWD to adjust plug/packer positions
  - Stacking lateral wellbores to reduce spacing in multi-pay basins
  - “Super-fracs” using significantly higher proppant (sand) amounts
  - Re-fracturing horizontal wells to offset decline

- **Decreasing Environmental footprint:**
  - Limiting freshwater use in fracturing
  - Recycle and use of produced/flowback waters for fracturing
  - Reducing gas in air, sound emissions while fracturing
Lowering Completion Cost

Pads drilling lowers drilling and completion costs
Lowering Completion Cost

Maximizing sand rail transfer lowers cost

Minimizing sand truck transfer lowers cost

Increased sand use improves (EUR/NPV)

Improved Completions
5,176' average lateral length
2,025 average lbs/foot sand
$6.84MM average cost

Old Completions
5,008' average lateral length
1,128 average lbs/foot sand
$6.73MM average cost

Improved Economics:
- ROR increased by ~40% per well
- NPV15 increased by ~$2 MM per well
2014 Frac Sand Usage - 50% growth

Total Consumption (Billion lbs.)

2008-2013 CAGR = 35.52%
2003-2013 CAGR = 30.15%
Lowering Completion Cost

Stacking and staggering horizontal wells lowers cost

Source: Laredo Petroleum
Small in comparison to other water users the oil & gas industry struggles to secure a “social license” to use water on a large scale.
Lowering Environmental Footprint

Minimize Trucking
Pumping and Pipelines
Temporary
Integrity
Distance
Permanent network
Link super sources to storage locations
Noise Mitigation

Source: Ceres – Hydraulic Fracturing & Water Stress
Industry’s Approach to Produced Water

- Increase use of produced water in fracturing
- Develop fluids that use high salinity water with minimal treatment OR without any treatment
- Develop chemistries to mitigate the effect of interfering ions
- Lower amount of water disposal
- Reduce trucking cost and number of trucks on roads
- Explore novel approaches to moving sand and water – possibly as slurry
Lowering Environmental Footprint

1. Chemicals
2. Ozone Oxidation
3. Nano-filtration
4. Hydrocyclones
5. Deionization
6. UV

Source: Apache Corporation
Treatment of Produced/Flowback Water

10,000 barrels/day modular unit

- Ozone generation
- Ultra-violet (bacteria)
- Activated carbon (BTEX)
- Ultra-filtration (suspended solids, iron)
- Mixed media filtration (suspended solids)
- Nano-filtration (sulfates, hardness) clean brine output
- Reverse Osmosis (boron, dissolved solids) fresh or low-boron output
- Ozone + induced gas flotation (organics, suspended solids, & bacteria)

Function:
- DAF Module: Clarifies water to 15 micron range
- Ozone Module: Oxidizes polymers, kills bacteria
- Mixed Media Module: Clarifies water to 5 micron range
- Ultra Filtration Module: Clarifies water to sub-micron range
- Nano Module: Reduces hardness, sulfates
- RO Module: Reduces boron, TDS

2500 barrels/day truck mounted unit

Source: Omni Water
Success Can Happen Quickly

Eagle Ford Oil production
thousand barrels/day

Eagle Ford Natural gas production
million cubic feet/day

Oil +31 thousand barrels/day month over month

Gas +115 million cubic feet/day month over month
Thank You, Gracias